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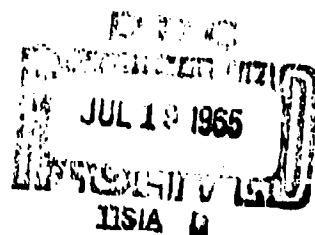
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ENVIRONMENTAL DESCRIPTIONS
OF RANGER TRAINING AREAS.

Part 3. Fort Benning
Area, Georgia.



The University of Tennessee
31 August 1964

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31 August 1964

To: The Director, WES
Attention: WESSE

From: E. Carl Shreve
Project Coordinator

Subject: Contract No. DA-22-079-eng-333. Sponsored by Army Materiel
Command Project No. 1-T-0-21071-A-131.

It is a pleasure to submit herewith the report on "Environmental Descriptions of Ranger Training Areas, Part 3. Fort Benning Area, Georgia." With this final report under the present contract, The University of Tennessee group wishes to again acknowledge the support and encouragement given by the United States Army Materiel Command and the Corps of Engineers, Waterways Experiment Station, and to extend its gratitude for having been allowed to participate in the MEGA project.

Respectfully submitted,


E. Carl Shreve

Department of Civil Engineering
The University of Tennessee

ENVIRONMENTAL DESCRIPTIONS

OF



TRAINING AREAS

Part 3. Fort Benning, Georgia

Area Evaluation Section, Embankment and Foundation Branch,

Soils Division

U. S. Army Waterways Experiment Station, Corps of Engineers

Vicksburg, Mississippi

Contract No. DA-22-079-eng-333

Sponsored by

Army Materiel Command

Project No. 1-T-O-21701-A-131

Department of Civil Engineering

The University of Tennessee

Knoxville, Tennessee

31 August 1964

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PLATE

1. Elongation Number	Rolled, Separate
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3. Dissection	Rolled, Separate
4. Profile Area	Rolled, Separate
5. Peakedness Index	Rolled, Separate
6. θ Values	Rolled, Separate
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ENVIRONMENTAL DESCRIPTIONS OF RANGER TRAINING AREAS

PART 3. FORT BENNING, GEORGIA

I. INTRODUCTION

A. Report Coverage

This report completes a University of Tennessee study entitled Environmental Descriptions of Ranger Training Areas begun in June, 1962, sponsored and supported by the Army Materiel Command and the Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi. This study, a part of the U. S. Army Research and Development Board Project MEGA, has been concerned with three U. S. Army Ranger training areas located in north Georgia, Eglin Field, Florida, and Fort Benning, Georgia. Reports designated Part 1 and Part 2, dealing with the north Georgia and Florida areas, respectively, have been previously submitted. The third and concluding report on the investigation contained in the following pages consists of the results obtained in the Fort Benning phase of the study followed by some summary comments regarding the whole study. Areal maps accompanying the report represent the compilation of macro-geometric and vegetational data from the Fort Benning area drawn to a scale of 1:20,000.

B. Location

The Ranger training area at Fort Benning, Georgia is located

mainly in southeastern Chattahoochee County in west central Georgia with a small portion along the eastern boundary extending into Marion County (Figure 1). The training area consists of two sections designated West Area and East Area which are separated by a distance of $7 \frac{3}{4}$ kilometers. The West Area lies between longitudes $84^{\circ} 47' 32''$ W and $84^{\circ} 50' 49''$ W and latitudes $32^{\circ} 17' 17''$ N and $32^{\circ} 20' 37''$ N, and the East Area lies between longitudes $84^{\circ} 39' 09''$ W and $84^{\circ} 41' 33''$ W and latitudes $32^{\circ} 18' 7''$ N and $32^{\circ} 21' 19''$ N. The two portions cover approximately 36.3 square kilometers within those boundaries.

The West Area is situated southeast of the headquarters section of Fort Benning, near Columbus, Georgia, and 1.2 kilometers west of the town of Cusseta, a name by which the westernmost portion is alternately referred. The East Area lies 7.3 kilometers east of Cusseta, which is located in Chattahoochee County, and the community of Glen Alta, Marion County, is on the southeastern tip of the East Area, which is alternately referred to as the Glen Alta area. Both areas lie generally southeast of the Harmony Church area on the Fort Benning Military Reservation.

From Columbus, Georgia, principal access to the West Area is provided by U. S. Highway 27 from which a segment of the old Columbus-Cusseta Road branches and runs along the northeastern boundary of the area. The Fuhrman, Jamestown, and Lightning roads follow the northwestern

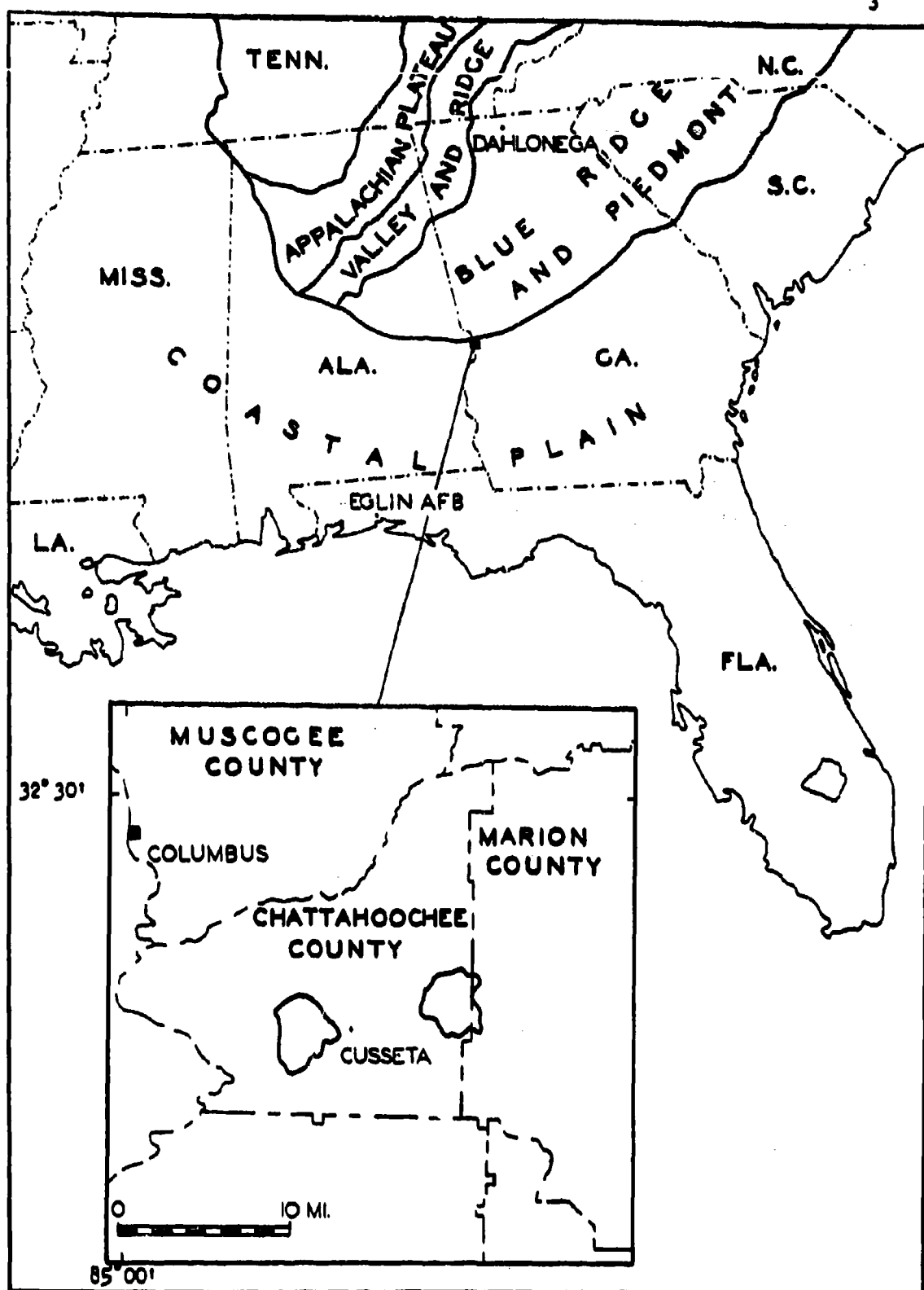


Figure 1. Regional setting and location of the Ranger training area, Fort Benning, Georgia.

western, and the southern to eastern boundaries of the area, respectively. Principal access to the East Area from the west is by way of U. S. Highway 27 to the east side of Cusseta, then northeast on Highway 23 which more or less diagonally bisects the East Area. The East Area can be reached from Columbus also by travelling Highway 103 for a distance of 35.4 kilometers, then proceeding on Acorn Road southwestward for a further distance of 1.8 kilometers. The Central of Georgia railroad track line forms the southern boundary, and Hollis Creek and Schley Pond form the western boundary of the East Area. The stream flowing into Schley Pond from the east a short distance north of Red Diamond Road forms the northern boundary. North to south, Acorn Road, Highway 26, and Glen Alta Road form the eastern boundary. A number of military roads within the two areas furnish additional access. The Ranger training area is included on portions of Army Map Service Series V 845 topographic maps 4048 IV SE, Ed. 4 (Cusseta) and 4048 I SW, Ed. 4 (Glen Alta). On these maps, vertical (west to east) grid lines 02 and 08, and horizontal (south to north) grid lines 74 and 81 enclose the West Area; grid lines 15 and 22, and grid lines 76 and 83 enclose the East Area. These lines provide a coordinate reference system utilized in the report for locating purposes.

C. Personnel

Professors E. Carl Shreve, Department of Civil Engineering,

Drs. Fred H. Norris, Department of Botany, and R. E. McLaughlin, Department of Geology and Geography, continued in the same coordinating and supervising capacities as in Parts 1 and 2 of the investigation and compilation of the reports.

Professors D. C. Jameson, Jr., Department of Civil Engineering, and Franklin Robinson, Hiwassee College, and Mr. C. James Dunigan, now at East Carolina College, supervised and engaged in the collection of field data as at Eglin Field. Again as before, Professor Robinson contributed to the synthesis of vegetational data and development of the vegetation map, and Professor Jameson and Mr. Dunigan directed the procedures for obtaining macrogeometric data and the preparation of the cartographic presentation on macrogeometry.

Mr. Dunigan continued the statistical analysis of data and prepared the critique on sampling and macrogeometry appearing in the last section of the report. Drs. Norris and McLaughlin have organized and prepared the balance of the report.

D. Acknowledgments

At Fort Benning, Lieutenant Colonel John R. Fitzpatrick, Jr. continued to provide the high level of cooperation experienced by the investigating team during its association with the Ranger Department, U. S. Army, throughout its range of training operations from north

Georgia to Florida. In this terminal report it is a distinct pleasure to pay tribute to this fine organization.

Professors Charles C. Thigpen and David S. Chambers, Department of Statistics, University of Tennessee, gave generously of their time to Mr. Dunigan in discussion of several aspects of statistical analysis, sharing no responsibility, however, for the mathematical treatment contained in this report.

Finally, Mrs. Ruby C. Miller, Department of Civil Engineering, and Mr. Thomas E. Young, Engineering Experiment Station, deserve special thanks for their contribution toward the reproduction of the final reports.

II. PHYSICAL DESCRIPTION OF THE FORT BENNING AREA

A. Physiography

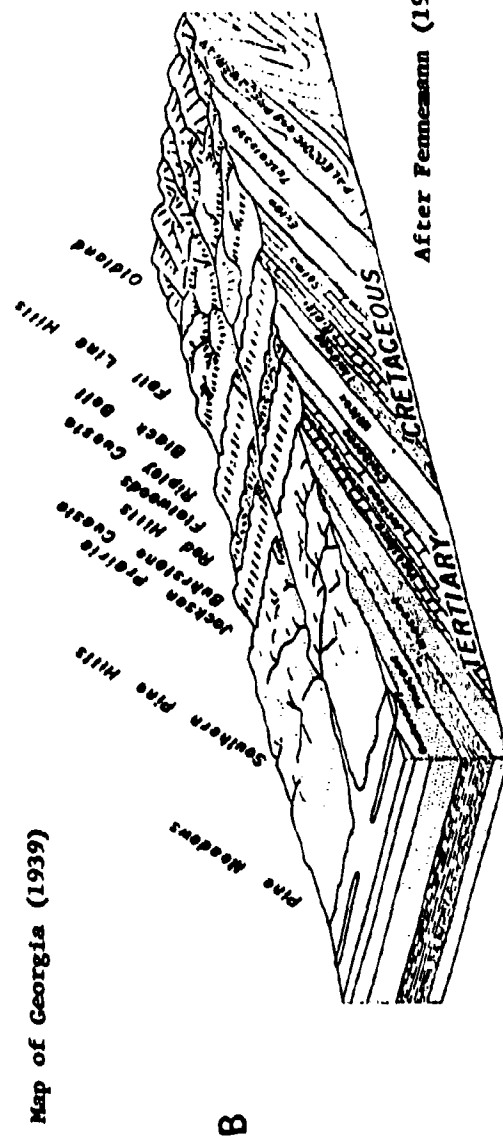
The area described in this report lies along the inner margin of the Coastal Plain Province (Figure 1, p. 3) and, compared to the location of the Eglin Field area, represents the other extreme in age, elevation, and geographic position respecting this physiographic division of the southeastern United States. Although the surface materials were similarly derived and to a large extent have the same composition and lithologic development, differences in topographic position and in the effects of hydrologic factors, longer exposure due to greater age, and contrasts in the structural attitude of stratigraphic units have produced a distinctive terrain in the Fort Benning area.

The Fort Benning Ranger training area is entirely within the subdivision of the upper coastal plain lying immediately south of the arbitrary physiographic boundary referred to as the Fall Line, where more resistant crystalline rocks of the Piedmont Province are succeeded southward by the less resistant formations of the coastal plain. Rather than a topographic bench with falls in descending streams, as in North Columbus, the boundary is most often marked in the southeast by the development of a belt of hills rising to nearly 244 meters and forming a distinctive type of topography. These hills have been referred to as the Fall Line Hills and Sand Hills (Figure 2).



From Geologic Map of Georgia (1939)

A



B

Figure 2. General geology of the Fort Benning area (A), and physiographic relationships of coastal plain formations (B).

In the vicinity of Columbus, the Sand Hills are capped by the bright red, conglomeratic sand, sandy clay, and clay beds of the Tuscaloosa formation of Late Cretaceous age overlying mottled purple, reddish brown, and variegated soft to less weathered saprolite of Piedmont gneiss, schist, and pegmatite in which residual structures can still be seen. South and east of Columbus, weathered sediments of the Tuscaloosa are exposed in roadcuts as the ascent up the rolling hills toward Fort Benning is made (Figure 3A). Proceeding southward, younger formations appear above the Tuscaloosa until the latter disappears completely and exposures then become entirely comprised of beds of Eutaw or younger age (Figure 3B).

B. General Geology

Stephenson in Veatch and Stephenson (1911) described the Cretaceous formations of this section of the coastal plain in considerable detail and to a degree of accuracy not matched by most subsequent work covering the area, including that of Cooke on the state geologic map of Georgia (1939). Cooke (1943) essentially up-dated the terminology of Stephenson.

In the stratigraphic nomenclature used by Stephenson, the outcropping formations in the Fort Benning Ranger area would be referred to as the Tombigbee sand member of the Eutaw formation and the Cusseta sand member of the Ripley formation. Eargle (1955) in the most recent work



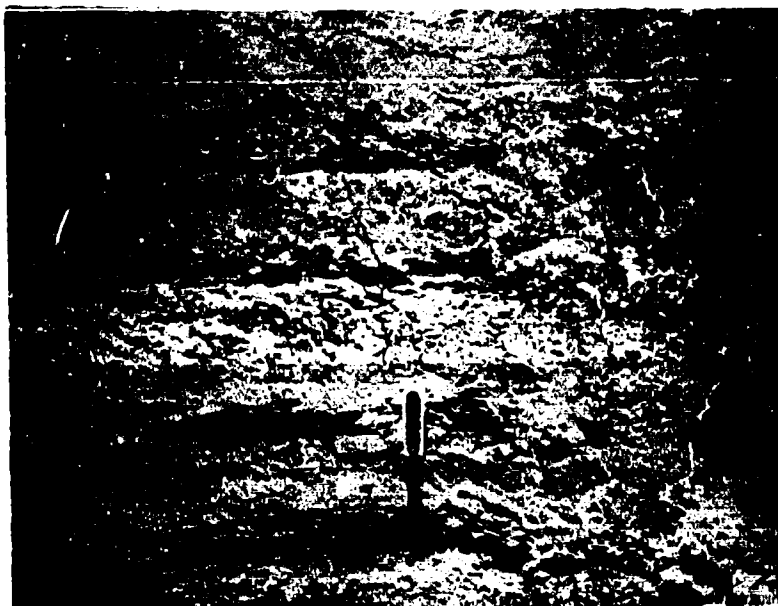
Figure 3A. Eutaw formation overlying Tuscaloosa sand and truncated by terrace deposits. Southeast edge of Columbus near highway to Fort Benning.



Figure 3B. Eutaw formation. Highway 27, southeast of Columbus.

in the area recognizes the distinctive lithology of the upper part of the Eutaw formation as described by Stephenson and considers it as being equivalent to the Blufftown formation earlier defined by Veatch (1909). Eastward the separation is not apparently clear and LeGrand (1962) interprets the Cusseta, Eutaw, and Blufftown as intergrading in a lateral facies relationship. Whatever the case, in the Ranger area of Fort Benning, beds described as Blufftown and Cusseta formations, members, or facies are the principal geological materials underlying the terrain and with a relatively small representation of the Ripley formation constitute the stratigraphic column with which the area is concerned. In the case of the Blufftown and Cusseta formations, the identifying characteristics employed by Ergle (1955) have practical application in the Ranger area and were used in making the stratigraphic judgments used in this report.

The older and stratigraphically lower Blufftown formation consists largely of a laminated, more or less sandy, fossiliferous, carbonaceous, gray clay (Figure 4) or fine sand underlain by a basal unit of coarse, distinctly but irregularly cross-bedded, coarser sand. The formation has a total thickness of around 122 meters. Except for surficial deposits on the higher ridges along the easternmost tip, and occasional higher places south of Weems Pond and along the southern margin, this formation is exposed on the surface throughout the West Area in the



A



B

Figure 4. Blufftown formation, West Area. Clay laminae close-up (A), and gully erosion (B) in the formation.

Ranger training section of Fort Benning. In fact, the Blufftown formation makes up the greater part of the rolling hills over the whole reservation.

West Area generally has an elevation less than 450 feet, increasing in a northeasterly direction from a low of 91.4 meters near Weems Pond (03.5 x 77.2) to a high on the ridge area cited above at 158.5 meters (06.5 x 77.7) (Figure 5). The basal sand unit of the Blufftown holds up the ridge area cuesta-fashion, and Highway 27 as it forms the north-eastern to eastern boundary of the West Area is constructed on it. The very micaceous fine sand with ancient worm borings in places and finely laminated clay beds, often fossiliferous, are the principal lithologies encountered in this area.

The thick basal sands of the Blufftown formation dip to the south and are overlain by the dark gray, laminated, silty clay which forms the surface material in much of the central and southwestern portion of the West Area. Blufftown outcrops composed of this member in places are traversed with difficulty during the rainy seasons. Separating the lower coarser sand from the clay in many places is a fine sand member which contains platy ironstone concretions developed along joints and similar partings, often along conspicuously parallel lines. The general elevation at which the sandy lower portion of the Blufftown grades into the upper clay portion is 106.7 meters. 1.2 or 1.5 meters of sandy, reddish residuum occurs on the surface of this formation commonly.

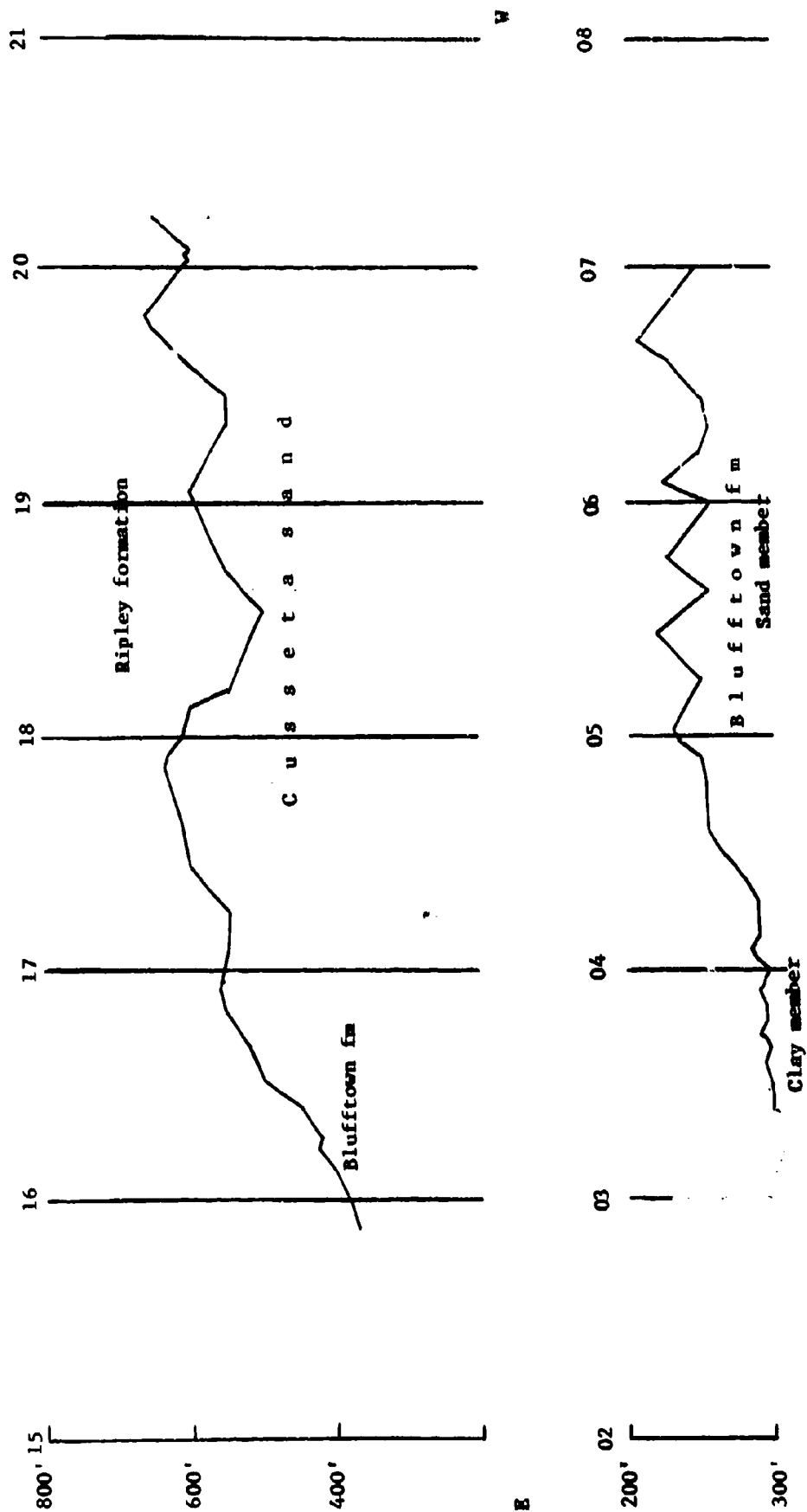


Figure 5. East-West profiles in Fort Benning Ranger area. Top. Along horizontal grid line 79, East Area. Bottom. Along horizontal grid line 76, West Area.

Eastward toward the East Area on Highway 27 near the junction with Highway 26, the Blufftown formation can be seen in contact with the overlying Cusseta sand in the town of Cusseta and elsewhere (Figure 6). Farther east, coarse sands appear near the top of the Blufftown and the contact becomes more difficult to determine. However, above 137.2-152.4 meters in elevation the Blufftown is entirely covered by the Cusseta formation in that direction. Entering the East Area from the west or southwest, Ochillsee Creek and tributary valleys have been cut down into the Blufftown so that this formation outcrops along the westernmost margin of the area. Above these western valleys, beginning at about 137.2 meters in elevation, 60 meters or more of sediments belong to the Cusseta formation (Figure 7). Thus the Cusseta constitutes a major portion of the surface material in the East Area.

The Cusseta sand is basically a coarse, cross-bedded red to yellow unconsolidated sand with a fine gravel at the base and a few beds of finer, micaceous sand interbedded with coarser sand. Lenses of dark brown kaolinitic clay occur in places. On some of the higher hills in the eastern part of the East Area the surface is blanketed with ironstone concretions weathered from the Cusseta. In most places the formation underlies a meter or more of reddish residual sand.

The East Area, as in the West Area, rises in an easterly direction from a low of 109.7 meters (16.0 x 78.3) on the western

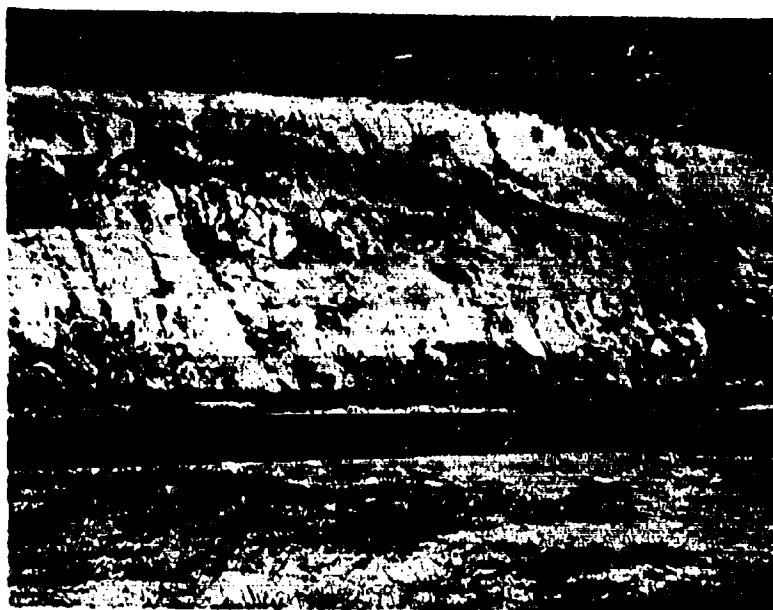


Figure 6. Cusseta sand overlying Blufftown formation, Fort Benning area.



Figure 7. Cusseta formation, East Area.

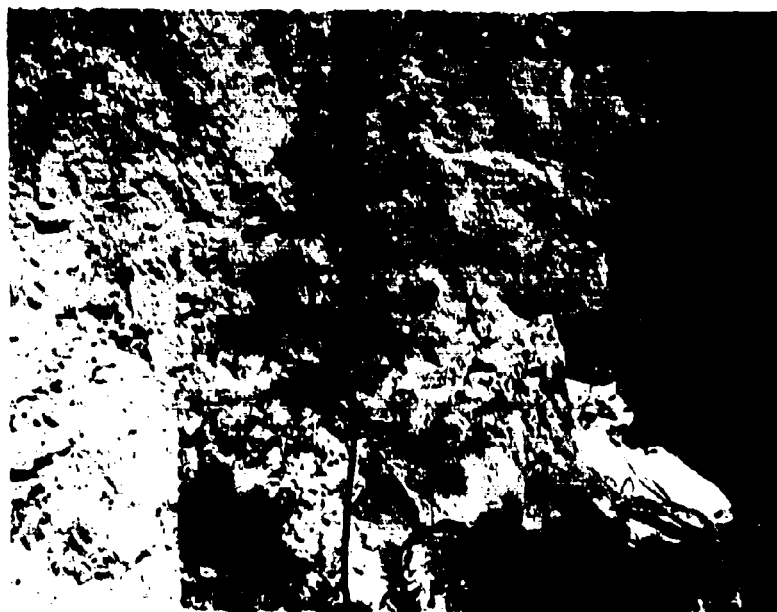
margin to a high of 222.5 meters (20.5 x 80.7) on the west (Figure 5, p. 14). Above approximately 198-215 meters in elevation, the Ripley formation overlies the Cusseta sand. Spurs from this relatively narrow outcrop belt of the Ripley formation, paralleling the eastern margin of the East Area, project westward toward the center of the area. Along horizontal grid line 81, one of these spurs extends better than half way across the area and Red Diamond Road has been built along it in this section.

The Ripley formation may be represented by a gray, calcareous, clayey, very fine sand or dark gray clay but in the East Area it is most conspicuously represented by a clayey, coarse sand with rather thick beds of blocky, deep red clay underlying the sand. Overlying the pale sands and thin white clay beds of the Cusseta formation in vertical exposures, the base of the Ripley formation is set off sharply from the older formation below. Some of the better exposures of the Ripley formation are in deep, rather spectacular gullies, which are made more so by the growth of large trees from their bottoms (Figure 8).

Weathering and leaching of the formations described above, most of which produce a sand residuum, have resulted in a superficial covering of loose, gray to reddish sand, varying in thickness from a few centimeters to 2-3 meters. Dissection has produced the "sand hill" effect (Figure 9). However, these formations all strike in a general



A



B

Figure 8. Deep gully exposing red clay of the Ripley formation.

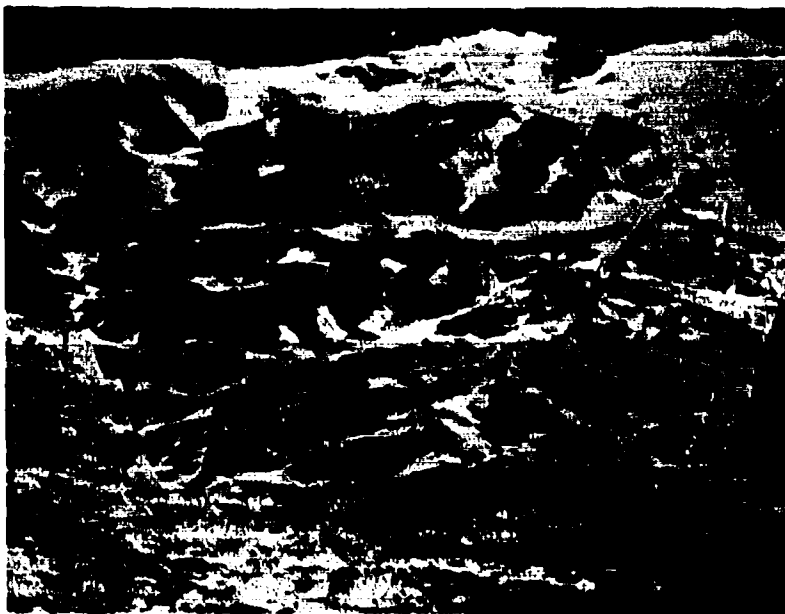


Figure 9. Sand Hill topography at Fort Benning shown by training model.

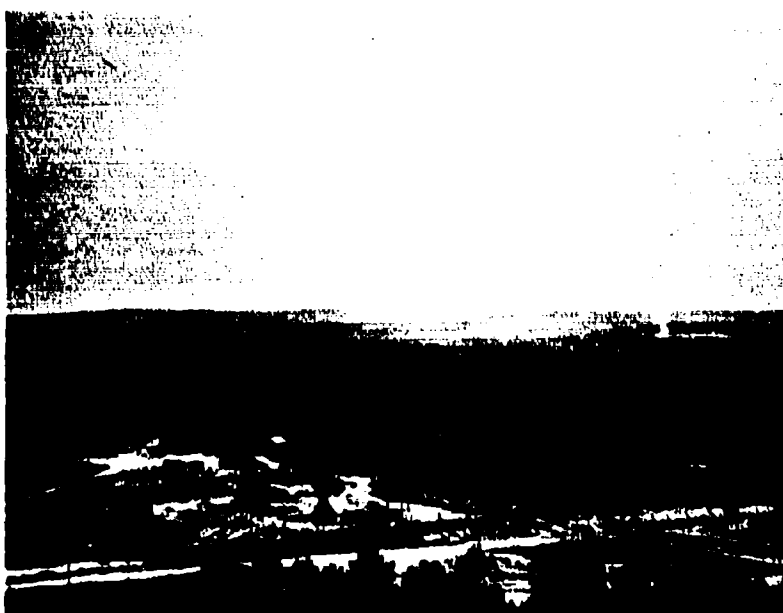


Figure 10. View toward East Area in direction of Cyclone Road-Red Diamond Road intersection. Cusseta, Blufftown, Cusseta, and Ripley formations from foreground to skyline, respectively.

direction between N 60° E and N 75° E and dip southward from 20 to 35 feet per mile (Eargle, 1955), the angle of dip increasing with lower stratigraphic position. Therefore, surface outcrops of the more resistant beds have a ridge-like cuesta profile (Figure 10, p. 19) which is obscured somewhat by the hill-producing dissection. North- to northeast-facing slopes are steeper as a result of the attitude of the underlying beds and the opposite ridge slope angle is less. North-south profiles drawn through both the East Area and West Area bring this out (Figure 11).

C. Soils

It was not possible within the portion of time allocated to the Fort Benning phase of the investigation to conduct even a superficial descriptive survey of the soil types present in the area. The limited observations made in the Ranger training area regarding soils are presented in the following generalized account as annotations to the reports of others who have studied the formation and distribution of soils in the area in more detail.

In an erosion survey conducted by the Soil Conservation Service (Fuller, et al., 1934), the Fort Benning area, along with most of the westernmost section of the Sand Hills was mostly mapped as destroyed by gullying with a few small areas (eg., around Cusseta) having moderate sheet erosion and frequent gullies. Earlier, a soil survey of Chatta-

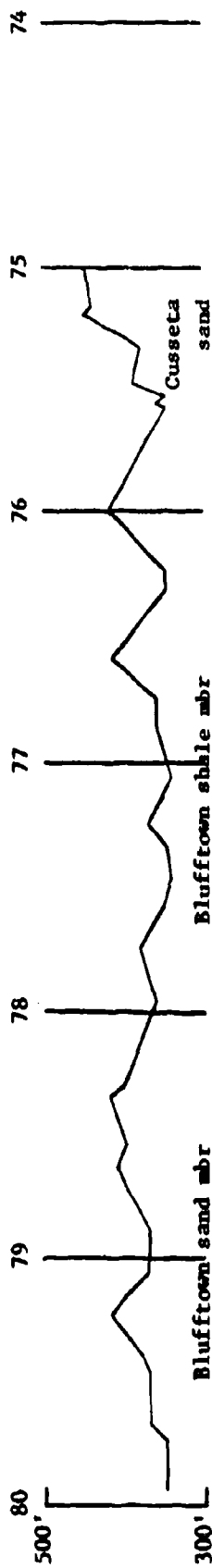
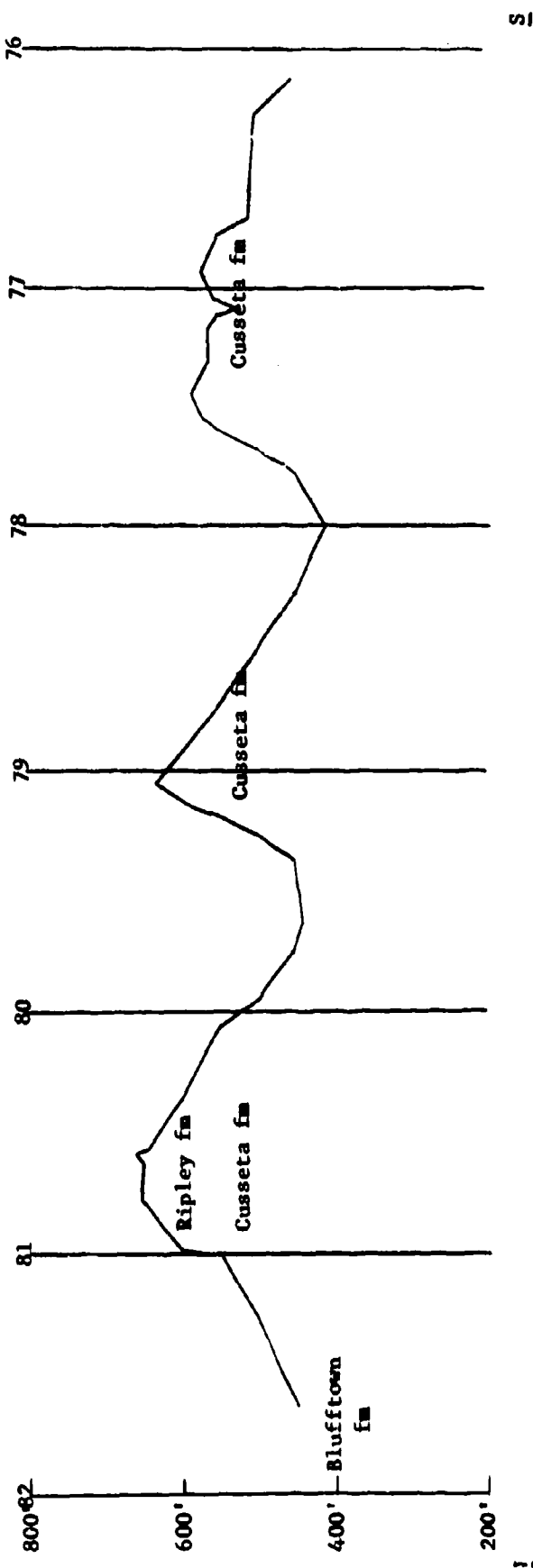


Figure 11. North-South profiles in Fort Benning Ranger area. Top along vertical grid line 18, East Area. Bottom. Along vertical grid line 05, West Area.

hoochee County (Knobel, et al., 1928) had limited the condition of extreme gullying to the narrow ridges of the higher portions of the county and to some valleys. In the case of the Ranger training area, the designation of rough, gullied land was given to most of the East Area lying above 137 meters in elevation. Whether either the length of time between surveys and the longer period of use as a military reservation (established in 1922) or the scale of mapping employed, accounts for the conflict in views is unknown. Certainly, since the time of the 1928 survey adjustment of the range of gullied land in the Fort Benning area would have to be made.

In the Sand Hills area, shallow to deeper surface sand is widespread and commonly overlies sand with interstitial clay, clay, or clayey sand, depending on the lithologic character of the Cretaceous parent material. Limited or absent runoff from the more or less incoherent surface materials results in eluviation of silt, clay, and mineralogic fractions to lesser or greater depths where hardpans and other similarly impermeable layers develop. Interspersed with the sands are soils developed on parent materials representing other sedimentary environments on the ancient shallow sea floor, carbonaceous and calcareous sandstones, shales, marls, and sandy limestones, among others. Thus, the development of soil types is rather varied in contrast to the sandy appearance of much of this section which is accentuated by the common

production of surface sand residuum through weathering by otherwise distinctive lithologic types.

Walker and Perkins (1958) characterize the Sand Hills belt as a rolling upland with deep Kershaw, Lakeland, and Eustis series soils predominating on the drier sites, with small areas of Gilead, Vacluse, and Hoffman soils occurring to a lesser extent. In the rather more detailed survey of Knobel, et al. (1928), none but the Hoffman type was mapped in the whole of Chattahoochee County. The higher, better to excessively drained sand soils were referred to the Norfolk and Ruston series. In general, these soils coincide with the portion of the area underlain by the Cusseta sand. The similarity of these soils to soil type 10 (University of Tennessee, 1964) at Eglin Field is close.

Most of the West Area is mapped in the 1928 survey, the only one apparently ever conducted in the area, as Susquehanna clay and descriptions of the variations of this soil type fairly well coincide with observations of soils developed over the Blufftown clay member. There is no equivalent soil type at Eglin Field. Ridge areas on the north and east in the West Area show alternating Norfolk, Ruston, and Susquehanna patches and these conform in position with outcrops of the Blufftown and Cusseta formations along the ridges as noted in the previous treatment of general geology. A similar discontinuous pattern of soils and related geology occurs along the western margin of the East Area.

A few samples of soil were collected from the outcrop areas of each of the two main soil producing formations in the Ranger area, The Blufftown formation in the West Area and the Cusseta sand in the East Area. For textural comparison, the results of the analysis are shown below:

	Sieve Size				
	10	40	80	200	Pan
1. Location: Vegetation Site 4. 201 g. from 3-6" depth.	(2.0)	(.42)	(.177)	(.074)	
Weight retained (g.)	1.0	30.5	51.0	94.5	24.0
Weight passed (g.)	200.0	169.5	118.5	24.0	
% passing	99.4	84.4	59.0	11.9	
2. Location: Vegetation Site 118 200 g. from 3-12" depth.					
Weight retained (g.)	0.6	126.6	53.8	12.5	6.5
Weight passed (g.)	199.4	72.8	19.0	6.5	
% passing	99.7	36.4	9.5	3.3	

The first sample listed came from soil developed above the clayey member of the Blufftown formation occupying sites intermediate in elevation in the West Area. The second sample came from soil developed over Cusseta sand in the East Area.

D. Litter and Humus

Litter and humus measurements were taken at most of the vegetation sites at Fort Benning. Tables I and II list the data collected according to area. Site descriptions include any evidence for operational or erosional disturbance which could be ascertained. Between 60-80% of all

TABLE I

Litter and Humus Data: West Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
1	Scattered pine, sweet gum; shrubs, broom sedge. Troop and vehicle disturbance, burned over.	1.3-2.5	.64	.32	.64-2.5	11.1/120°
2.	Scattered pine; dense sweet gum, myrtle, sumac, willow oak, blackberry.	1.3-2.5	.32	trace	5.1-7.6	Flat
3	Former clearing covered with sweet gum, shrubs. Considerable wash, burn evidence.	.64-2.5	.32-.64	trace	2.5-7.6	6.5/0°
4	Scattered pine, old and young. Dense sweet gum, etc., brush, some openings. Footpaths, drainage ditch, old gullies, vehicles.	1.3-2.5	.32	trace	5.1-7.6	12.0/150°
5	Scattered pine, poplar, sweet gum, oak. Footpath remnants; vehicle evidence. Bottom land.	4.4-5.7	.64-1.3	.32-.64	2.5-5.1	Flat
6	Scattered pine, small sweet gum, dense myrtle, etc., underbrush. Some gullies; litter-covered paths and tracks.	1.3-1.9	.64-1.3	.64	2.5-5.1	11.5/335°

TABLE I (Continued)

Litter and Humus Data: West Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				Slope Direction
		L	F	H	A ₁	
7	Scattered pine, fairly dense understory of sweet gum, etc., brush. Grass in open areas. Gullies; litter covered paths and tracks.	.32-2.5	trace-.64	trace-.64	2.5-5.1	6.9/300°
8	Briars, broom sedge, <u>Lespedeza</u> , cerise, etc., old field with broad, shallow gullies.	trace	—	—	none	4.5/140°
9	Tall poplars, oaks, pines, dense seedling, vine understory. Centered on actively eroding gully 15.2 m. deep.	3.8-5.1	1.9	1.3	3.8	15/40°
10	Closely-spaced sweet gum, poplar stand; saw briars, no low shrubs. Steep slope leading to flat-sloping terrace to flat. Accumulation in pockets.	2.5-3.8	.64-1.3	.64-1.3	2.5-7.6	13.0/27.5/280°
11	Scattered pine, grass, low weeds; scattered shrubs, sweet gum, oak over brow of rounded sand hill with flat top. Vehicle turning area.	Scant except in depressions: 1.3-2.5 total.				.64 Flat top

TABLE I (Continued)

Litter and Humus Data: West Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
12	Pine 10-20 cm. dia., grass and scattered bush openings. Footpaths and tracks.	trace- 1.3	trace	trace	2.5-5.1	2.5/165°
13	Scattered small pines, closely scattered sweet gum-oak clumps with grass in open areas. Extensive gullying in old abandoned road and beyond. Humus in de- pressions mainly.	trace- 5.1	trace- .32	trace	.64-2.5	7.5/220°
14	Scattered pine; young sweet gum; fairly dense underbrush of sweet gum, etc. Recent troop activ- ity. No gullies.	1.9-2.5	.64	.64	2.5	8.75/75°
15	Scattered pine; dense hawthorn, pine, sweet gum understory 4.9-6.1 m. uniform height.	1.3-1.9	.64	.32	.64-1.3	Flat
16	Fairly dense, tall sweet gum, oak, poplar stand; dense seedling, grape vine, briar understory.	Limbs, sticks 2.5+	.64	.64	5.1	Flat
	Fairly dense pine stand; little ground cover. Considerable track, path, fire disturbance.	2.5-5.1	.64	.32	.64	4.5/175°

TABLE II

Litter and Humus Data: East Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
101	Fairly dense sweet gum stand. Honeysuckle, briar, seedlings, climbing vine ground cover. Vehicle and troop movement on flood plain.	1.3-5.1	.64	.64	2.5-5.1	Flat
102	Scattered pine, some sweet gum and oak. Several large gullies with trees in bottom present. Area open under trees; training area.	Scattered on top of mineral soil.				4.0/260°
103	Scattered pine; open understory, some sassafras. Litter accumulated in low places, otherwise thin cover over mineral soil.	2.5-3.8	1.3	.64	1.9	7.0/290°
104	Scattered pine, pine seedlings, grass, weeds. No disturbance apparent. Litter under pines, thin cover on sand otherwise.	5.1-7.6	2.5-3.8	.64-1.3	1.3	4.0/215°
105	Deciduous swamp. Muck accumulation.	1.3	5.1-7.6	12.8-15.2	sand	Flat

TABLE II (Continued)

Litter and Humus Data: East Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
106	Scattered pine; grass, briar, sumac, sassafras, weed undercover. Vehicular movement, old gun emplacements, troop movement, gullies.	1.3-3.8	.64-1.3	.32-.64	.64	4.4/not taken
107	Scattered pine; fairly dense stem thicket under pines to about 6.1 meters. Some vehicle and troop movement. Some gullying.	1.3-5.1	.64-1.3	.32-.64	2.5-5.1	11.0/310°
108	Pines with fairly dense myrtle and oak underbrush. Vehicle and troop movement. Gullying.	Scant to 5.1	0-1.9	0-.64	0-2.5	4.0/335°
109	Dense young pine stand with open grass area. Foxholes, gun sites, vehicle and troop movement. Gullies.	0-5.1	0-1.9	0-3.2	0-.64	5.5/250°
110	Broom sedge and weeds, several scattered shrubs. Old plowed field; some grown over gullies. Vehicle movement.	Scant litter on mineral soil.				4.0/40°

TABLE II (Continued)

Litter and Humus Data: East Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
111	Scattered oak and hawthorn; some grass clumps and weeds, several individual pines. Over-run by vehicles and troops.	Scant litter on mineral soil, primarily oak leaves and pine needles.				6.0/310°
112	Open field, broom sedge, briars, scattered persimmon weeds, scattered pines. Vehicles and troops.	Old weed stems with clumps of dogfennel; otherwise scant on mineral soil.				4.0/345°
113	Scattered pines, low brush, saw briars. Vehicles, troops, severe burning (dead pines); gullies.	Thin cover mainly pine needles on mineral soil. Much large dead-fall.				7.0/180°
114	Scrub oak, few scattered pine; fairly dense shrub undercover. Troops, vehicles, shallow gullies. Numerous twigs and sticks on ground.	0-5.1	0-1.3	0-.64	0-2.5	9.6/85°
115	Dense scrub (to 3m.) with open areas, saw briars, grapes. Troop and vehicle movement. L composed of coarse material-leaves, sticks, stems.	2.5-5.1	trace	—	none	9.5/350°

TABLE II (Continued)

Litter and Humus Data: East Area

Fort Benning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
116	Scattered pine with some oak; fairly open with grass and weeds; trees severely damaged and down. Vehicle and troop movement; severe gully- ing. Litter under pines, elsewhere scant.	2.5	1.3	trace	none	3.5/205°
117	Hawthorn thicket, some scattered pine and oak. Surface thoroughly cut up by past vehicles. Only 50% has litter cover.	1.3-5.1	1.3-2.5	1.3-1.9	trace	5.0/175°
118	Thinly scattered pine in open field, scattered shrubs, grass-weed ground cover. Severely cut up by vehicles and troops.	Thin scattering of litter on mineral soil.				8.0/205°
119	Oak, hickory, black gum; some scattered brush on ground. Troop movement. L present only in patches.	2.5-5.1	trace	.64-3.8		21.0/50°

TABLE II (Continued)

Litter and Humus Data: East Area

Fort Banning, Georgia

Vegetation Site #	Description	Thickness (cm.)				% Slope Slope Direction
		L	F	H	A ₁	
121	Fairly close-spaced scrub oak, occasional pine. 40% bare. Shelling, vehicle and troop movement, fox holes, some gullyng.. Litter in pockets.	0-5.1	0-.64	0-.32	0-trace	10.3/165°
122	Dense, large and small hardwoods with scattered pine.	5.1-7.6	1.3-1.9	.64-1.3	45.7+	2.0/not taken

sites in both areas showed evidence of operational disturbance in one form or another. Gully erosion, recorded for many of the sites, will be discussed in a later sub-section of the report.

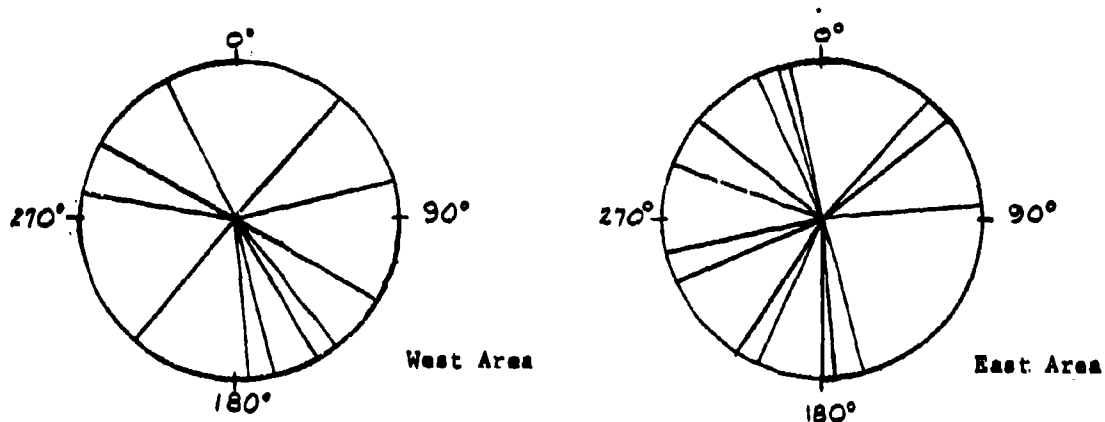
Comparing pine-dominated mor humus and hardwood-dominated mull humus distribution in the less disturbed sites, relative thickness of component layers and incorporation in the A₁ horizon appear to run true to form. Excessive disturbance either by military activity or extreme slope wash are no doubt involved in pattern anomalies of which there are several. Poor drainage in the flatter sites underlain by the dark clay of the Blufftown formation accounts for the few instances of large scale H or A₁ thicknesses.

Only a few cases of litter size approaching microgeometric dimensions were observed. One of these (Site 113, East Area) developed as the result of extensive burning. In the main, however, decomposition appears to keep pace with deadfall and the latter, as at Eglin Field, does not pose a serious trafficability problem.

Trafficability is affected to some degree by humus accumulation in a number of instances of relatively thin soil developed over silty or sandy clay, or clay on steeper grades in the West Area. An analog to the situation in the north Georgia (Dahlongega) upland appears to exist. On the one hand, clayey B horizons are exposed following removal by wash or slide, and humus provides the surface for pedestrian ascent

or descent. On the other hand, in the southern portion of the West Area, the parent material of similar properties is exposed at or near the surface and humus accumulations are again effective.

Along with the collection of litter and humus data at the vegetation sites, slope measurements were taken, first, as a possible insight into unexpected variations in this type of surface material, and second, in order to conduct a small scale experiment in taking ground samples of slope characteristics. The data are shown in the last column in Tables I and II. A summary of slope directions in each area at Fort Benning is shown below for comparison:



Not considering two extremes 4% and one 27 1/2% slope, the average slope in the West Area was 7.5%. Eliminating flat or immeasurable slopes and one 21% slope in the East Area, the average was 6.4%. In reference to the patterns of slope directions shown above, interesting concentrations of directions and complementary gaps appear but further

sampling is necessary before further discussion of them would be justified.

E. Cone Penetrometer Tests

Trafficability measurements were taken in the Ranger area with the cone penetrometer at five of the vegetation sites in the West Area and thirteen sites in the East Area (Plate 3). Data are recorded in Tables XII and IV.

In the West Area, all profiles appear to be normal or very nearly so. In the 6"-12" critical layer, all readings are well above minimal requirements listed in the soils trafficability manual (Dept. of the Army, 1959). However, no tests were made in the Weems Pond-Oswichee Creek drainage area in the west-central section. Conditions during wet periods could be important although there is little relief.

With one possible exception, at the creek bottom site 101, all readings in the East Area show completely adequate traffic support strength. Profiles are considerably less uniform in the East Area owing quite possibly to the wider range of materials constituting the soils and to the greater relief. High readings at shallower depths along the eastern ridges appear to be associated with the less disturbed soils developed in the area underlain by the Ripley formation. The abnormal profiles are largely confined to the Cusseta sand-Blufftown formation area on the bordering slopes and in the bottomlands of Ochilsee

TABLE III
Fort Benning Cone Index Averages
West Area

Vegetation Site No.	Sur- face	Depth of Readings					
		3"	6"	9"	12"	18"	24"
1	33	213	245	278	284	300	
3	119	224	167	164	165	184	
4	83	200	252	240	251	300	
5	60	151	158	140	151	106	
6	85	188	170	219	244	266	
7	63	168	180	196	199	234	
*8	85	300+					
9	33	168	213	263	293	300+	
10	43	156	172	177	182	186	
13	127	227	236	264	288	300+	
14	40	170	200	224	231	269	
15	48	237	296	292	296	296	
	62	283	270	289	289	297	

*This site was an old field, soil was fine sand.

TABLE IV

Fort Benning Cone Index Averages

East Area

Vegetation Site No.	Surface	Depth of Readings					
		3"	6"	9"	12"	18"	24"
*101	37	96	75	105	80	81	
**102	69	202	276	276	278	300+	
103	35	110	192	184	140	134	
104	53	251	300+				
106	64	151	251	248	280	290	283
107	50	260	280	300	300+		
**108	20	273	300+				
**109	118	280	300+				
**110	75	300+					
**111	50	300+					
113	159	241	222	210	231	265	
114	21	162	161	201	156	163	
115	41	156	152	163	132	136	
**116	38	136	300+				
**117	21	217	280	300+			
118	37	225	256	214	195	213	
119	89	181	137	185	180	195	
121	36	188	164	134	144	146	
122	21	29	58	109	158	171	

*Clayey sand saturated at 12", recent rain.

**Evidence of vehicles.

Creek and tributaries. It is in this section that wet season conditions are apt to be most critical in the East Area. Again, as in the parallel case in the West Area, it is judged that data from such sites are needed before a complete appraisal of trafficability can be made.

F. Visibility Study

Visibility tests were conducted at most of the vegetation sites at Fort Benning in association with the vegetation sampling. The procedure used follows that outlined for a similar study at Eglin Field (University of Tennessee, Part 2, p. 46).

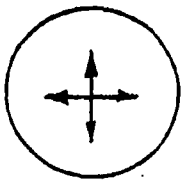
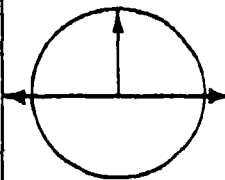
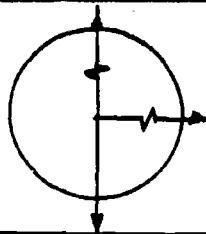
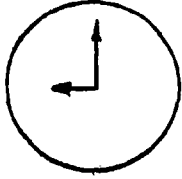
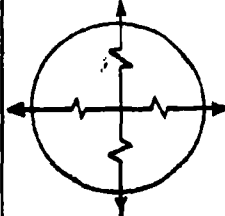
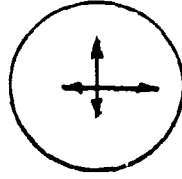
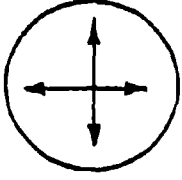
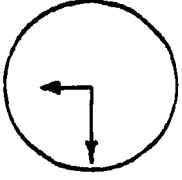
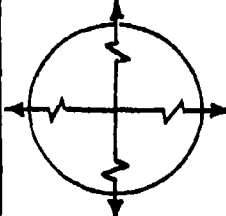
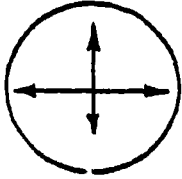
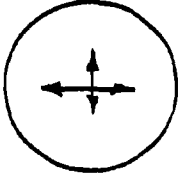
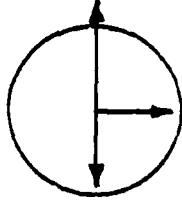
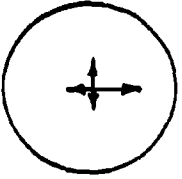
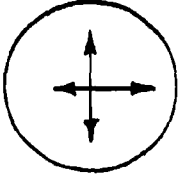
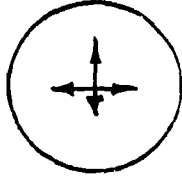
Measurements were made along the four major compass directions where practicable and visibility symbols were developed from the field data. Fifteen symbols selected from each area are shown in Figures 12 and 13 for comparison. Tables I and II, pp. 25 thru 32 may be referred to for the general vegetational patterns for the sites represented by the symbols, and vegetation diagrams submitted as a supplement to this report may be consulted for specific information.

In the West Area, visibility, as recorded, ranges from that determined for Site 1 (scattered, 15.3-30.5 cm. diameter pine and similarly dispersed gum and shrubs) to that measured at Site 3, a former clearing densely covered with gum and shrubs to a height of .6-4.6 meters. In the East Area, scattered pine, 20.3-37.8 cm. in diameter, with grass,

Site	Symbol	Site	Symbol	Site	Symbol
1		2		3	
4		5		6	
7		9		11	
12		13		14	
15		16		17	

Scale: 1" = 100 m.
 Circle radii: 50 m.
 Enclosing squares: 140 m.²

Figure 12. Visibility symbols, West Area, Fort Benning.

Site	Symbol	Site	Symbol	Site	Symbol
101		103		104	
105		106		107	
108		109		113	
114		115		116	
117		121		122	

Scale: 1" = 100 m.
 Circle radii: 50 m.
 Enclosing squares: 140 m.²

Figure 13. Visibility symbols, East Area, Fort Benning.

weeds, and low bushes at Site 106 can be contrasted with Site 117, a hawthorn thicket.

On the basis of site computations illustrated by the symbols shown, it would appear that visibility is more restricted in the East Area. However, the majority of sites in both areas have visibility ranges within 50 meters of the center point. Obviously, visibility characterization of large areas by this method is wholly dependent upon vegetation sampling density.

The extent to which such visibility indices might be applied to whole areas within the drawn boundaries of vegetation types has not been investigated. Further, in this regard, the degree of closeness of the local sample upon which the measurements were made to a "type specimen" of such vegetation types is not known at present.

G. Hydrology

The hydrologic environment at Fort Benning is controlled by two water systems, one operating on the surface, the other beneath. All water-related features in the area result from the discharge into one system, recharge of the other, or from an interplay of both, the latter due to the fact that the area lies in a zone of intersection between the two systems.

Both Fort Benning Ranger areas slope in a west-southwesterly

direction and the portions of each area in the direction of slope receive surface drainage from a single stream and tributaries, Oswichee Creek in the West Area, and Ochillee Creek in the East Area. These streams are part of the Chattoohoochee River system draining to the Gulf through the Apalachicola Basin. Some hydrologic cross-sections in the Ranger area are located and shown in Figure 14.

The streams of the Ranger area are sluggish, flowing through low-banked channels bordered by wide, swampy, densely wooded valleys and flood plains, typical of the streams of the upper coastal plain (Thomson, Herrick, Brown, et al., 1956). Areas parallel to streams contrast sharply with the vertically and laterally drained and excessively drained sandy uplands where vegetation is sparse and discontinuous. The interfluvial ridges cut transversely into hills are broad and flat or slightly sloping with moderately inclined sides. Much of the cultural development, including many of the transportation lines, follow the interfluvial ridges. In the Ranger area, an almost continuous ridge line and drainage divide forms a broad arc from the Harmony Church Area to the center of the East Area along which are located the major highways, a long portion of the Seaboard Air Line, and the town of Cusseta.

The ultimate tributary branches of the two major streams in the Ranger area are ephemeral and intermittent. Channeled mainly in incoherent sand, their temporary water supply is lost through influent

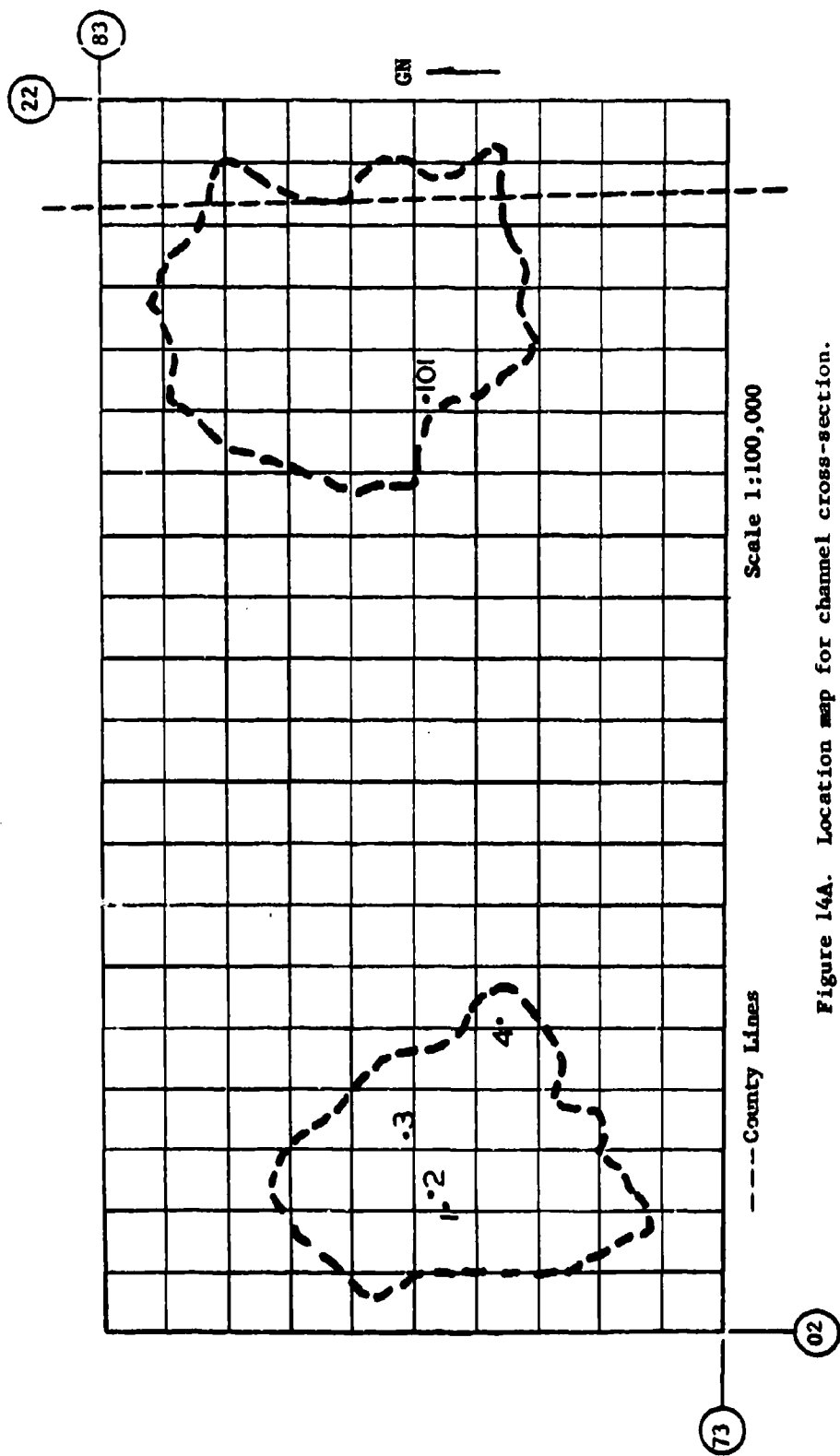


Figure 14A. Location map for channel cross-section.

Scale: 1" = 1 meter.

44

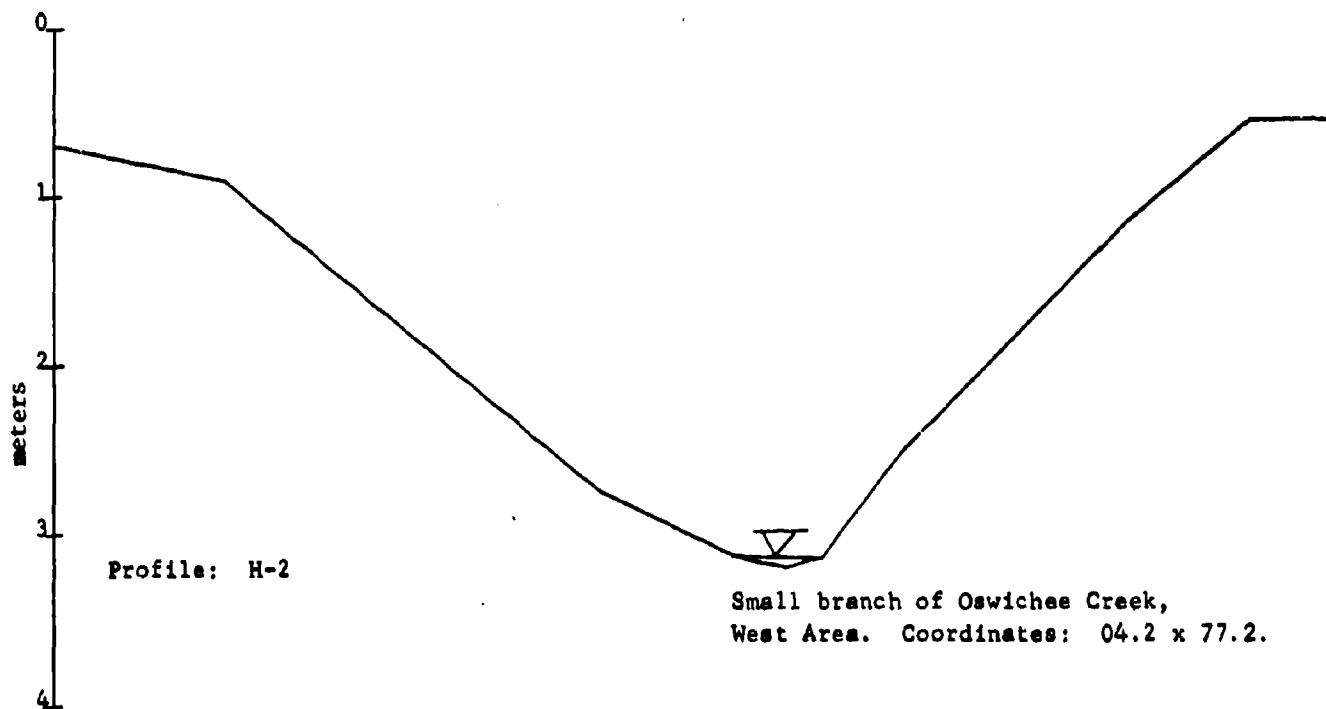
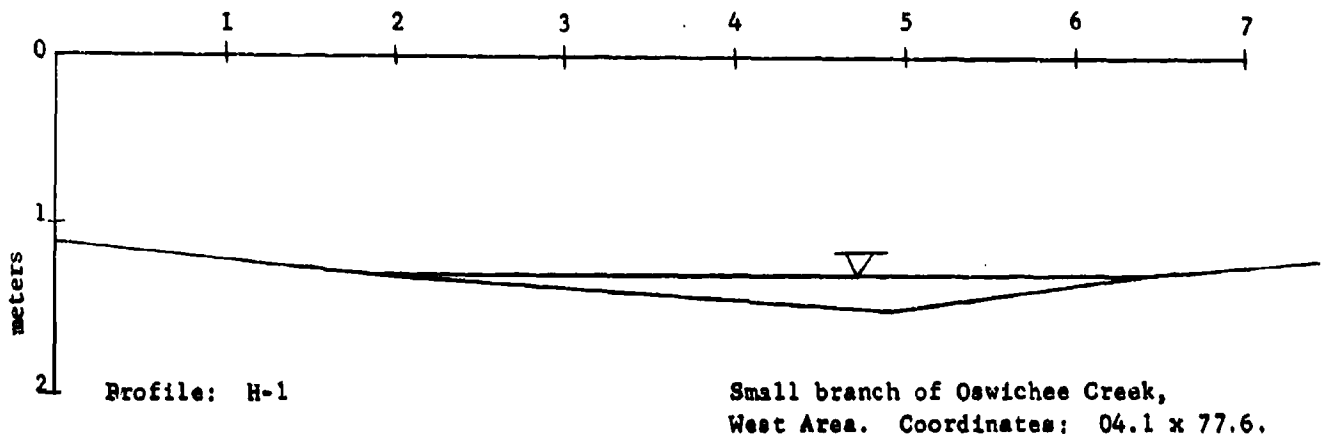
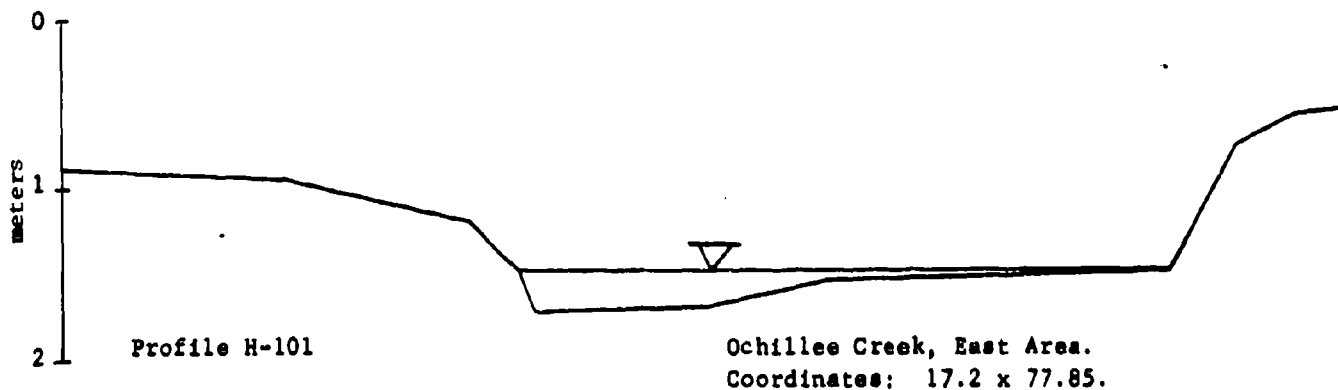
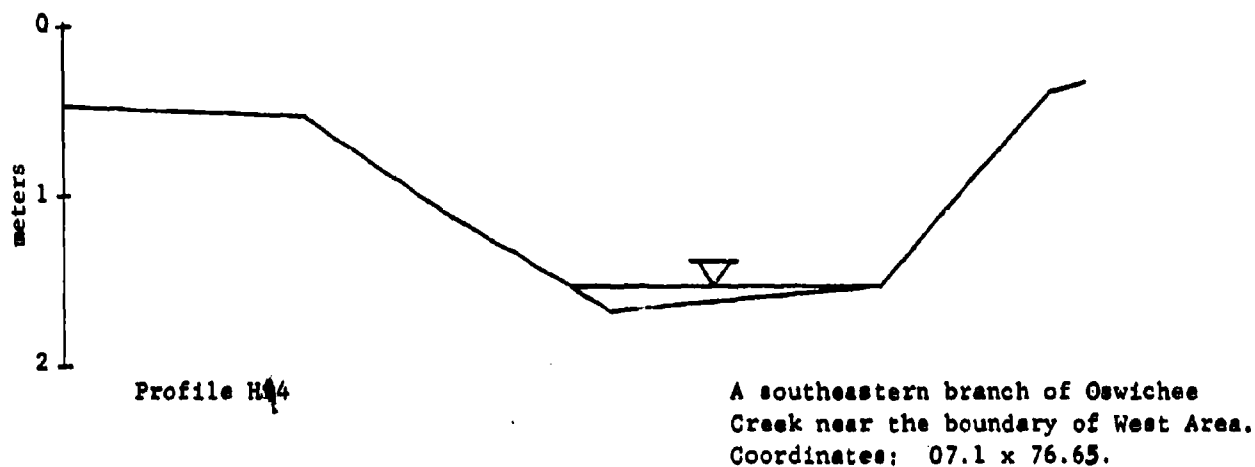
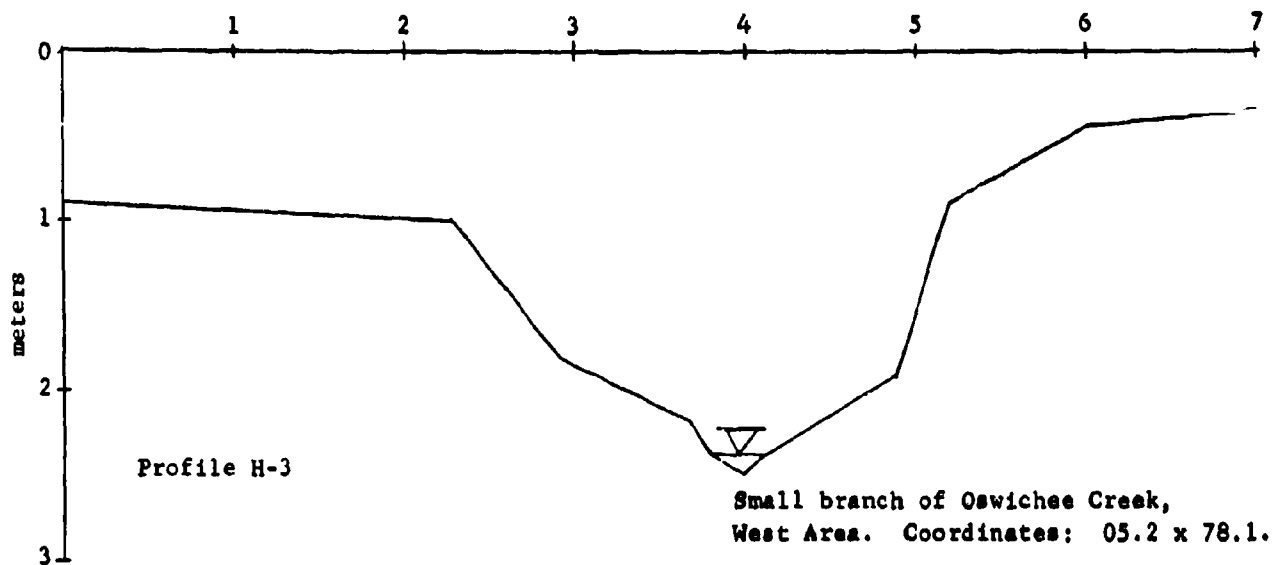


Figure 14B. Stream cross sections, Ranger area, Fort Benning, Georgia.

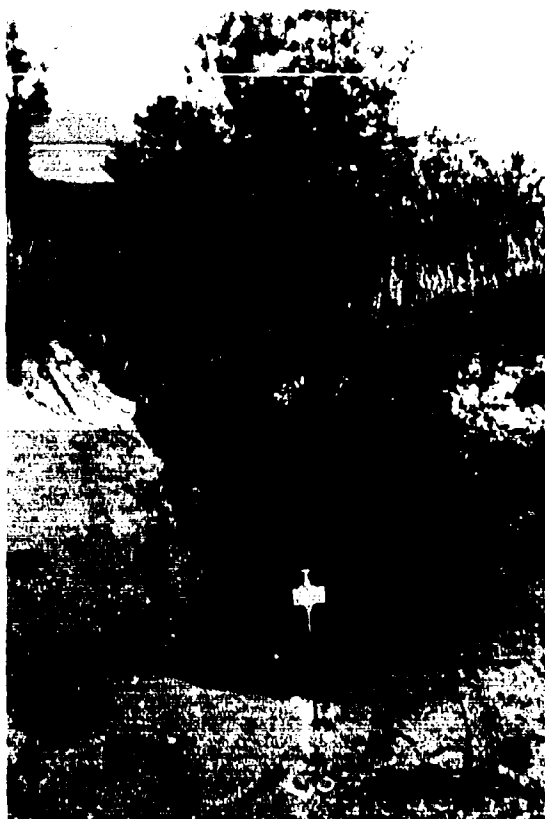
Figure 14B (Continued).

45



seepage. The two main streams are able to maintain relatively uniform flow because they have cut channels into shale or clay beds of the Blufftown and Eutaw formations and they are regularly recharged by seepage from the sands lying stratigraphically higher. Above the clay- and shale-lined lowlands, either relatively flat terrain or permeable soil prevent reservoir storage. Shallow basins have been dammed across the surface drainage system in the lowlands on the west side of each area to create ponds, Weems Pond in the West Area (Figure 15C) and Schley Pond in the East Area.

In the Chattahoochee Valley, coarse sand and gravel of the Tuscaloosa formation, silty shale and sand of the Eutaw formation, sand and laminated sandy clay of the Blufftown formation, coarse to fine-grained sand of the Cusseta formation, and the uppermost sand and thick clay beds of the Ripley formation together form a triangular-shaped lithosome with individual monoclinal beds dipping up to 55 to 60 feet per mile south-southeastward (Eargle, 1955). This geological arrangement of alternating pervious and impervious lithologies accompanied by structural dip provides for an extensive artesian system. The Fort Benning reservation is located across the recharge zone of this system. Outcropping permeable aquifer sands intercept precipitation through absorption, and, alternately, outcropping, less permeable aquiclude shales and clays intercepting other precipitation induce runoff if the gradient



A



B



C

Figure 15. Hydrologic features, Fort Benning Ranger area.
A, B. Stages in gully development. C. Meeks Pond.

is sufficient, temporary ponding if not. Any combination of aquifer and aquiclude can produce a flowing system varying in piezometric amplitude with the attitude and depth of the beds. The portion of the artesian system present in the Ranger area was described in an earlier section.

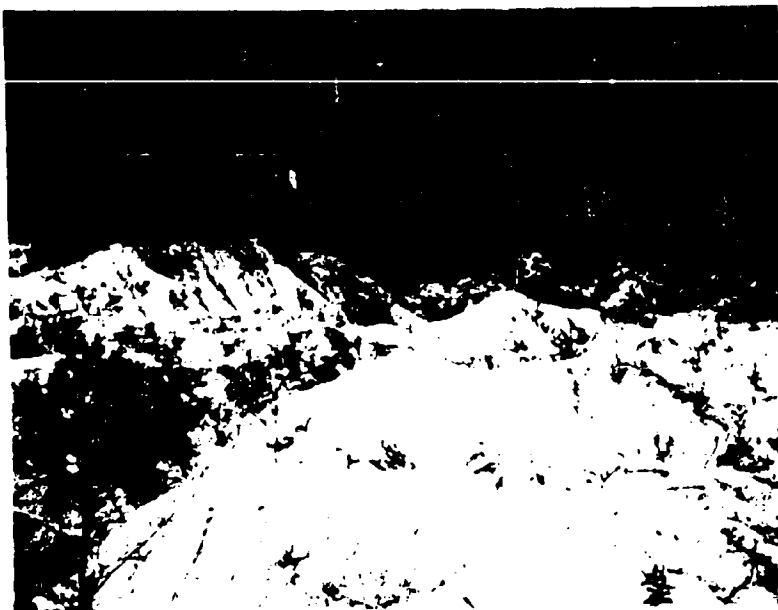
In the area of exposure of the Cusseta sand, much of the 127 cm. average annual precipitation is confined by beds of clay or fine sandy clay, either in natural stratigraphic position or secondarily developed as soil hardpans. Water percolating downward through the pervious sands is forced to move laterally or down dip, often emerging as springs on steeper slopes, in cuts, or at other points of interception. According to Thomson, Herrick, Brown, et al. (1956, p. 294), prior to 1953 the town of Cusseta obtained its municipal water supply from several such springs, and several ponds on the Fort Benning reservation owe their origin to similar circumstances. The same authors report (p. 292) that the city now receives water from the Cretaceous aquifer penetrated by a well to a depth of between 1100-1200 feet below the surface in which water rose to within 270 feet of the surface in 1953. Further, the relationship between surface runoff and the aquifer system is shown in a well at Fort Benning which taps the Tuscaloosa formation at a depth of 568 feet. Wet season (early spring) highs and dry season (late summer) lows fluctuate with the stages of the Chattahoochee River.

The most obvious hydrologic products in the Ranger area at Fort

Benning are the gullies recorded at many of the vegetation sites (Tables I and II, pp. 25-32) and much in evidence almost everywhere (Figures 15A and B, p. 47, Figure 16, and Figure 8, p. 17), their frequent occurrence having been previously noted in earlier sections of this report. Although initially planned, time did not permit a detailed study of these gullies. However, a brief discussion of them will be given in order to complete an otherwise inadequate survey of hydrologic features.

Even casual observation reveals at least two major types of gullies in the area, related directly or indirectly to the two hydrologic systems discussed above. The first of these types is associated with the less permeable Blufftown shale and sandy clay member and is thus typical of the West Area where this formation underlies much of the surface. This type has rounded surface boundaries, a shallower depth and narrower width, and appears to be primarily a runoff gully.

The second gully type (Figure 8, p. 17) is typical of the higher elevations, especially the ridge area along the eastern margin of the East Area. It is deep, wide, and steep-sided, and is floored by streams of sand moved short distances at a time during rains. This groundwater type is particularly characteristic of the outcrop belt of the Ripley formation in the East Area. Groundwater emerging at the top or at the base of impermeable Ripley clay along a bedding plane formed with a sandier member or with the Cusseta sand is the chief agent involved in



A



B

Figure 16. Extensively gullied areas, Fort Denning. Many of these originate as shell impact zones.

activating the colluvial processes which enlarge the gullies. Vestch and Stephenson (1911) and Eargle (1955) describe such activities to the south and east of the Ranger area in the Ripley formation or where that formation is in contact with the overlying Providence sand. This gully type has a parallel in the famous Providence Canyons of Stewart and Quitman Counties, Georgia, and in the steepheads at Eglin Field (University of Tennessee, 1964, Part 2).

Conceivably, a third gully type, combining the effects of both surface and subsurface erosion, is present. A detailed study of such gullies as developed at Fort Benning would seem to be in order inasmuch as they extend dimensionally across the macrogeometric-microgeometric interface.

III. MACROGEOMETRY

A. Elongation Number

The sample elongation values for the Fort Benning area are based upon two spot samples consisting of the two Ranger training areas. Figure 17 shows these values to be roughly normally distributed with a mean in the neighborhood of 0.46 and a standard deviation of about 0.114. Those terrain units which are atypical at about the 5% lower and upper levels among the sample group are shown on Plate 1. (The several terrain unit parameters of the Dahlonga, Fort Benning, and Eglin areas are compared in Section V, subsection A of this report.)

Graphs of the separate spot samples are shown in Figure 18. It will be noticed that they appear to be mirror images of each other. Closer examination, however, reveals that there is considerable overlap between them. The subjective decision to combine them into one sample "representing" the Fort Benning area is based on the fact that, while the two areas "reach" into two different types of terrain, they together appear to include most of the gradations of terrain within the vicinity of Fort Benning.

B. Relief

The local relief of the individual terrain units in the Fort

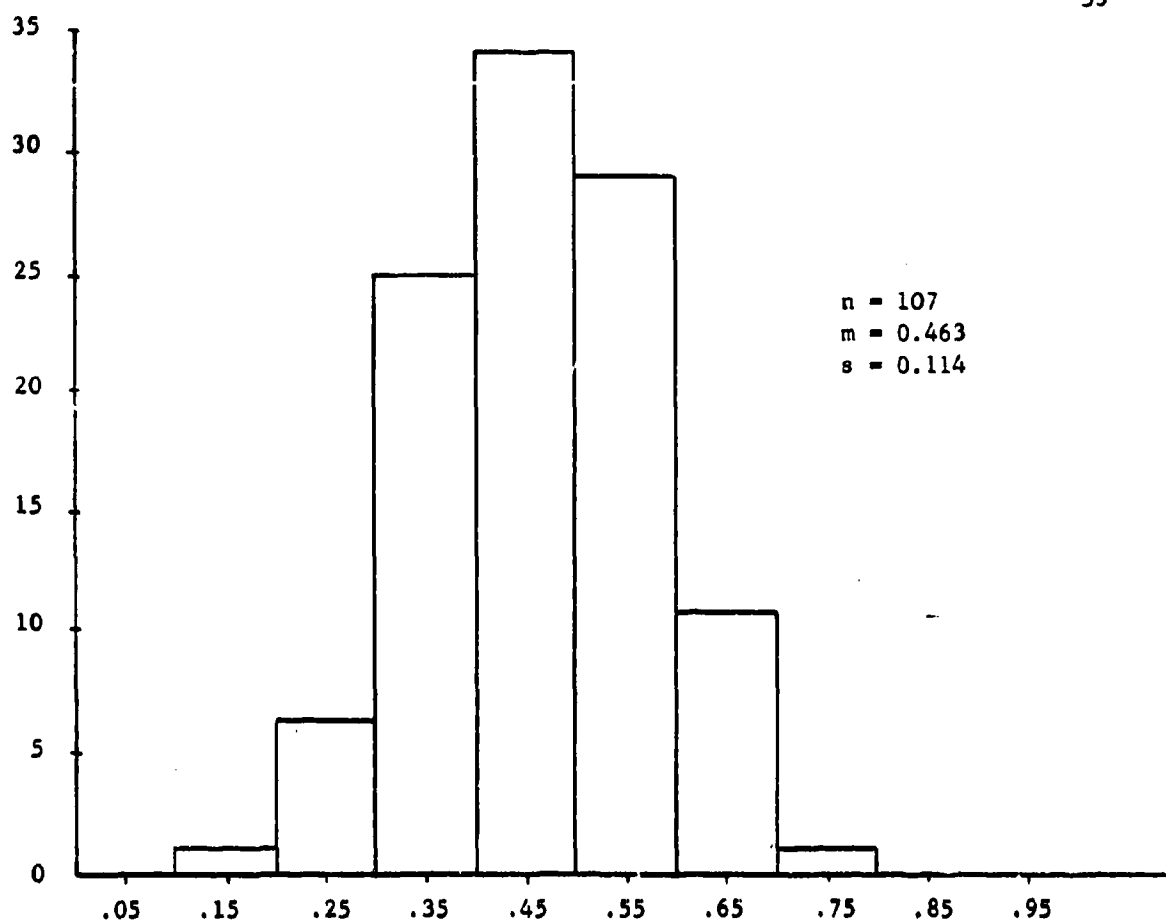


Figure 17. Frequency distribution of sample terrain unit elongation numbers, Ranger training areas, Fort Benning, Georgia.

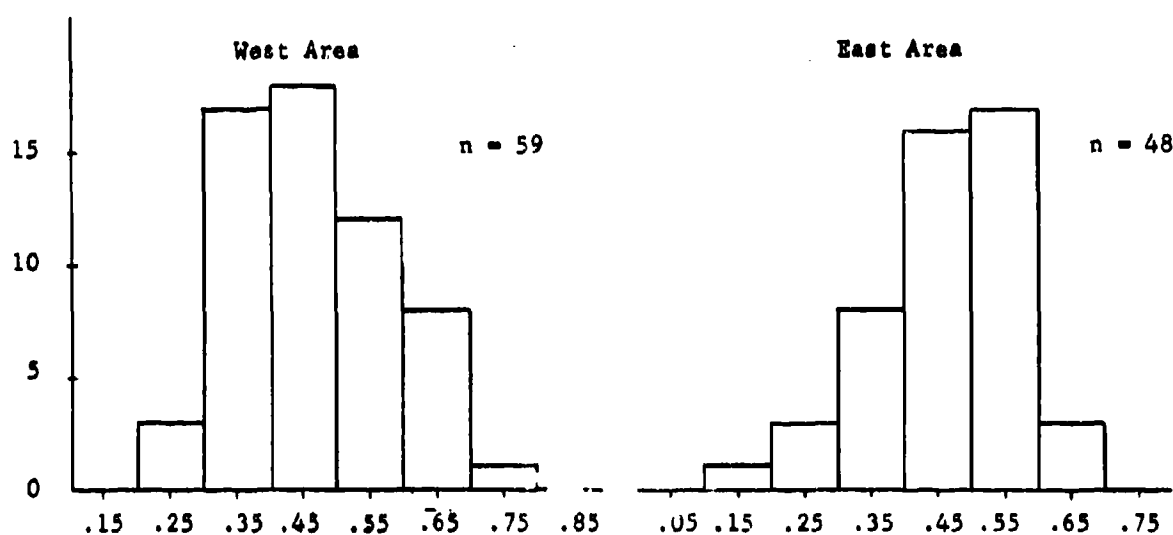


Figure 18. Frequency distribution of sample terrain unit elongation numbers, Ranger training areas, Fort Benning, Georgia.

Benning area does not appear to be great, being in the neighborhood of 150 feet at most. The vertical distance from the bottom of a local main-stream creek to the headwaters divide is likely to be considerably greater, but several terrain units are likely to be traversed in the distance.

Relief values between the two sample areas are somewhat diverse in their distributions. The East Area yielded a rectangular shaped distribution while the West Area seems to follow some distribution similar to that of the chi-square with a mean large enough for it to approach the normal shape (See Figure 19). In spite of this, however, the two areas were combined with the assumption of more nearly representing Fort Benning and vicinity as mentioned above with respect to the elongation numbers.

The graph of the relief values for the combined groups of Fort Benning terrain units is shown in Figure 20. The assumption of normality in determining the means and variances of these (and other sets of terrain units below) is not entirely justified; however, this matter will be discussed in the summary section. Plate 2 shows the terrain units with relief values lying 1.66 standard deviations from the sample mean. These values were determined from a logarithmic transformation. The transformation, however, is not a particularly good fit to a normal distribution.

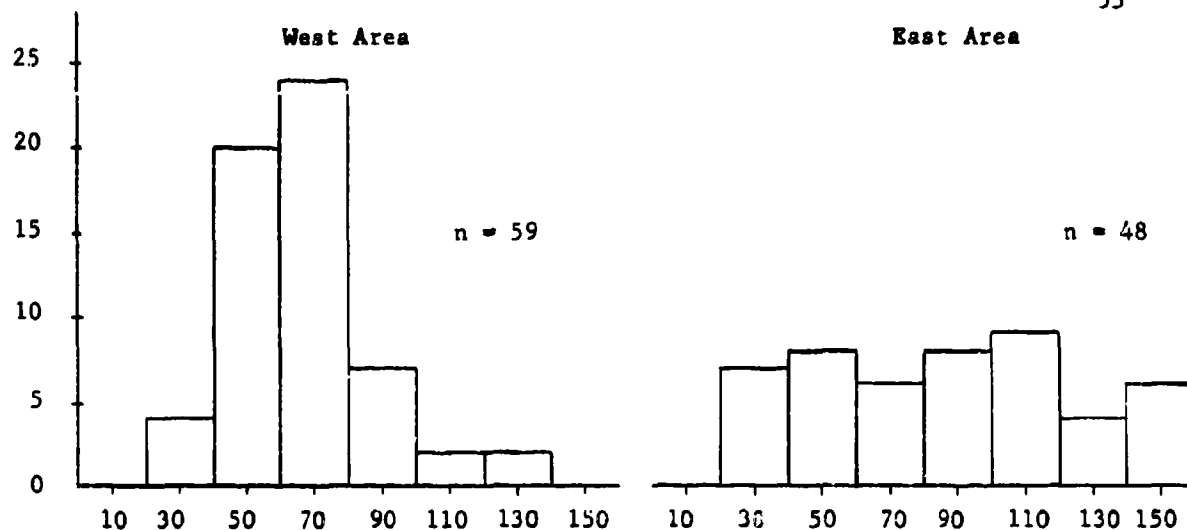


Figure 19. Frequency distribution of sample terrain unit relief (in feet) values, Ranger training areas, Fort Benning, Georgia.

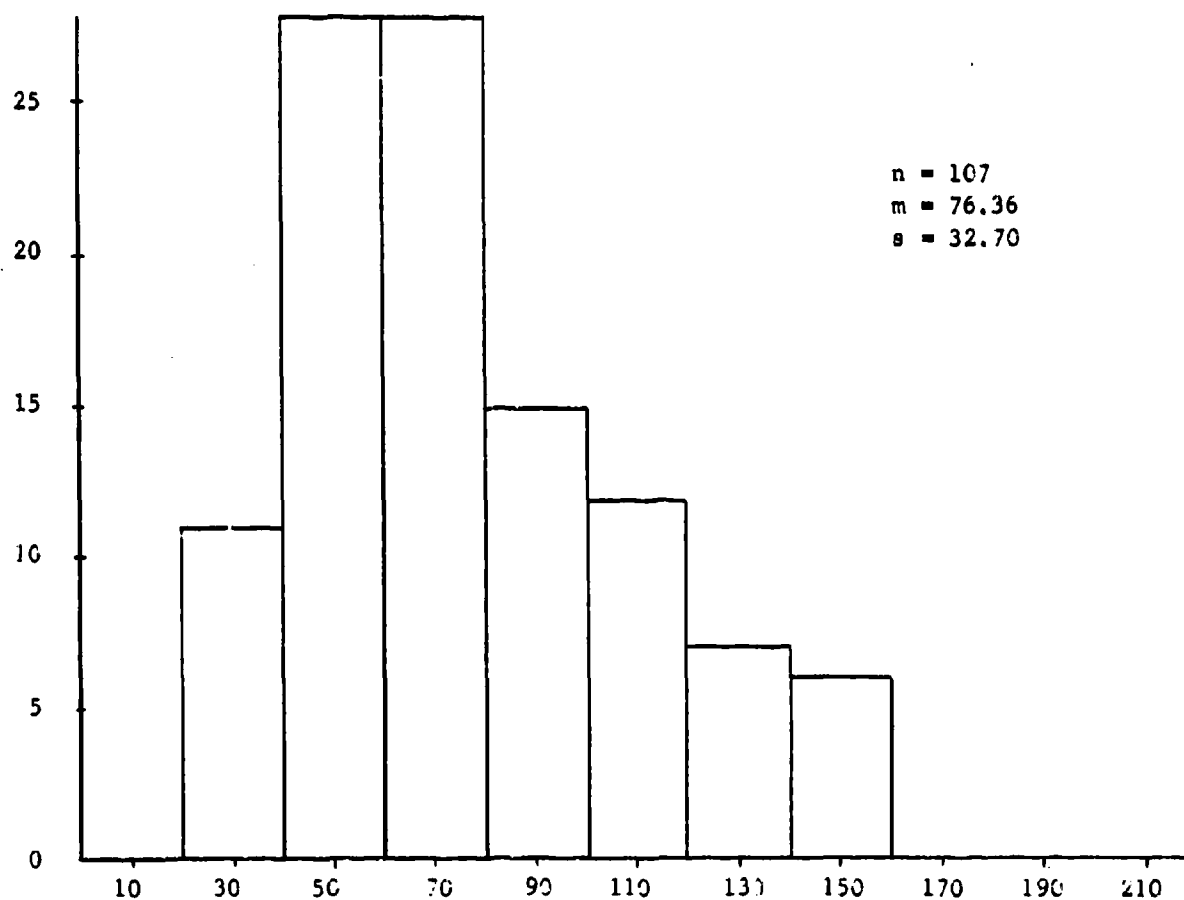


Figure 20. Frequency distribution of sample terrain unit relief (in feet) values, Ranger training areas, Fort Benning, Georgia.

C. Dissection

Like the relief values the dissection numbers are in some respects different between the East and West Areas as shown in Figure 21. The greater range of D-values in the East Area simply means less uniformity in the average base radius of that set of terrain units. In either instance, however, these relatively small knobs obviously cannot yield large base measurements. The combined set of values is shown in Figure 22. (See also Plate 3). As in the Dahlonega and Eglin areas, D-values tend to be skewed considerably more than other values; thus, a logarithmic transformation for determining the variance gives a fairly good fit. The matter of transformations is discussed in the summary section.

D. Profile Area

As indicated in the Dahlonega report, page 86, the A-values would be expected to cluster about a mean of 0.5. Unlike other terrain unit values of the Fort Banning area the A-values are not greatly different between the two sample areas. Figure 23 reveals that they do cluster about a mean in the neighborhood of 0.5. Examination of the very low and high values show that the "random" rays from which they were derived fell rather consistently along sags or ridges. This situation can yield only low and high numbers respectively. Plate 4 shows several terrain units which yielded "outlying" values.

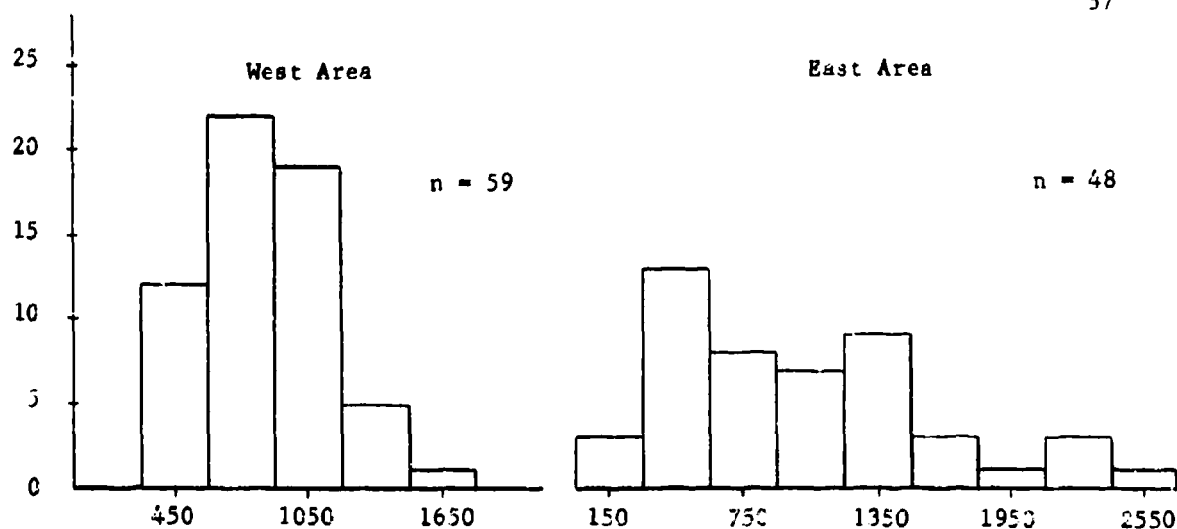


Figure 21. Frequency distribution of sample terrain unit dissection (in feet) values, Ranger training areas, Fort Benning, Georgia.

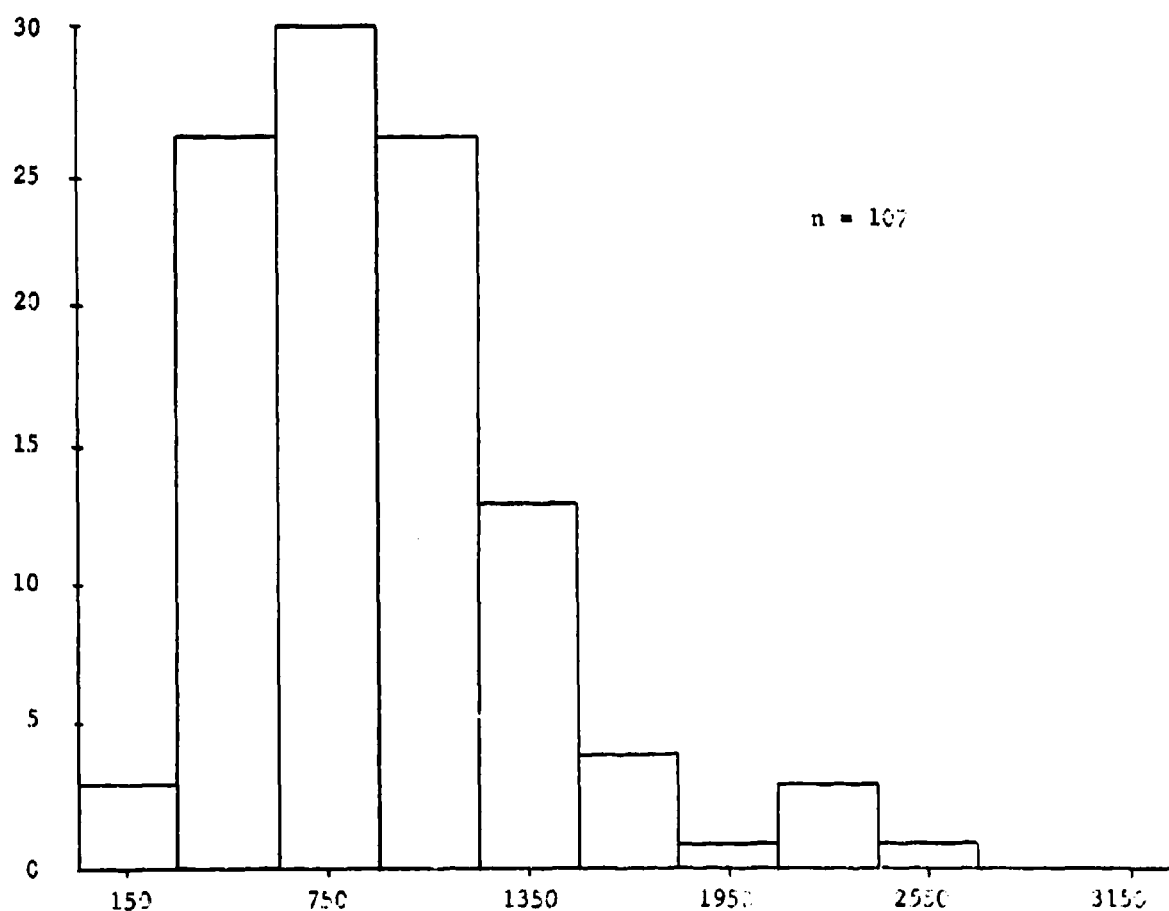


Figure 22. Frequency distribution of sample terrain unit dissection (in feet) values, Ranger training areas, Fort Benning, Georgia.

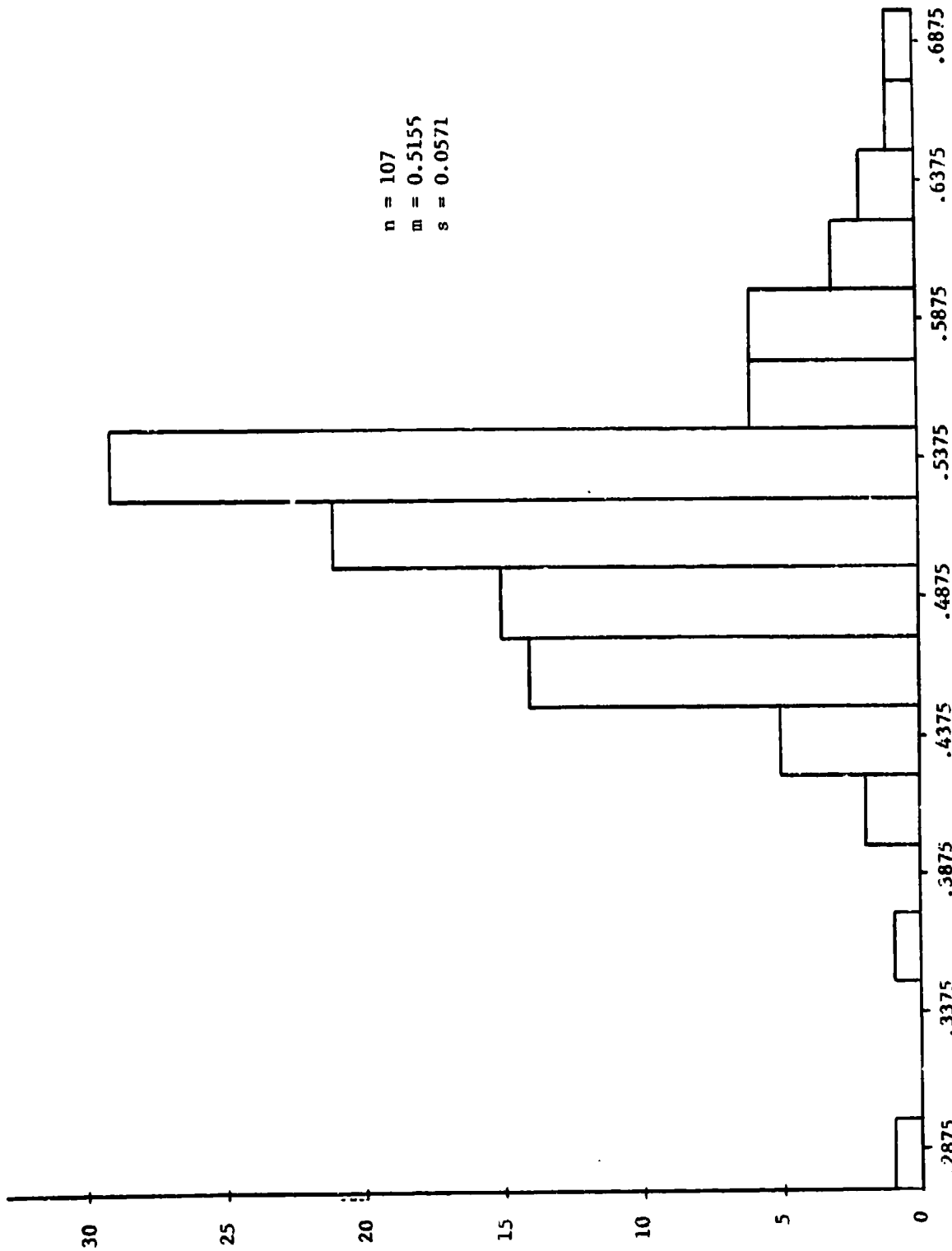


Figure 23. Frequency distribution of sample terrain unit profile area numbers, Ranger training areas, Fort Benning, Georgia.

E. Peakedness Index

The Peakedness Index, also referred to as the S-value, is a measure of the average slope of the top ten percent (in terms of relief) of the terrain unit. The values shown in Figure 24 are in terms of the tangents of the angles; they vary from slopes of less than 2° to more than 7° . The flatter the top of course, the smaller the S-value. Those terrain units unusually flat and those unusually peaked are shown on Plate 5.

F. Slope

The average slope for the entire terrain unit is represented by the θ -values. Since there is usually some amount of flattening at the top of a terrain unit, larger θ -values than S-values are to be expected. Those terrain units measured for this report varied from about 3° to about 9° . Gullying along a part of a terrain unit boundary may give rise to a relatively large slope value. This is particularly evident as was noted in the Eglin area where some exceptionally steep units may be observed in contrast to otherwise broad flat areas.

The θ -value is an average for several sides of a terrain unit; thus, a hill with a 30° slope on one side could, with two to four degree slopes around a large part of it yield a θ -value of 7° to 9° . (The matter of precision in models is discussed in the summary section.) Those terrain units with relatively low or high average slopes are shown

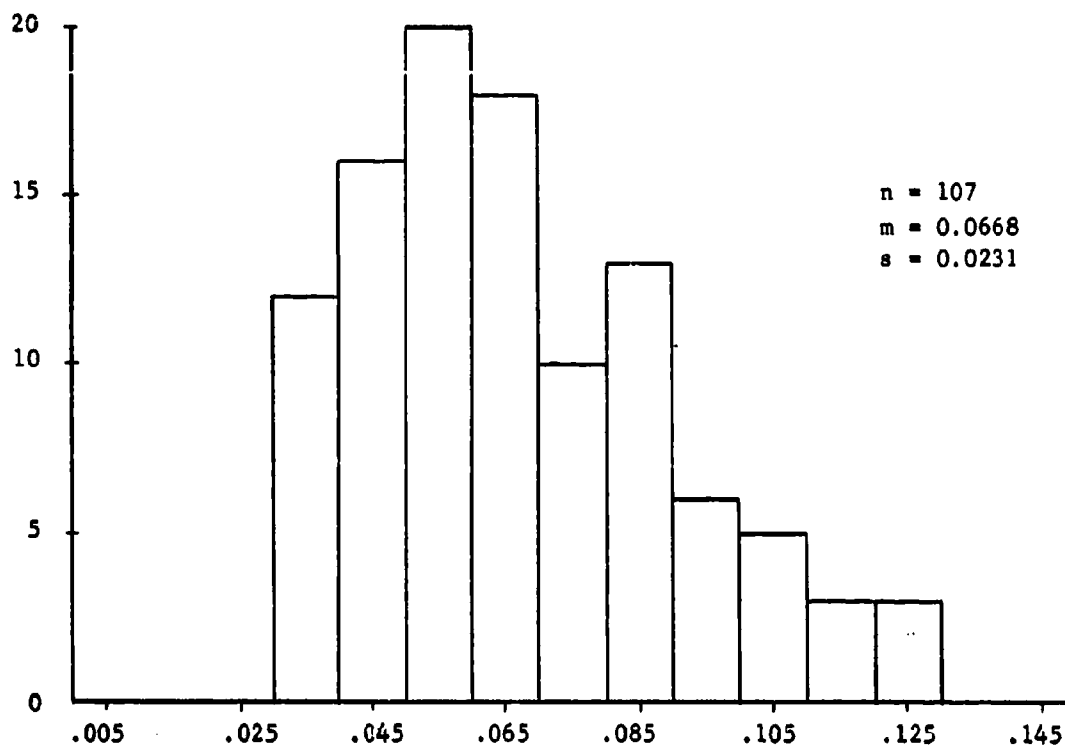


Figure 24. Frequency distribution of sample terrain unit peakedness index numbers, Ranger training areas, Fort Benning, Georgia.

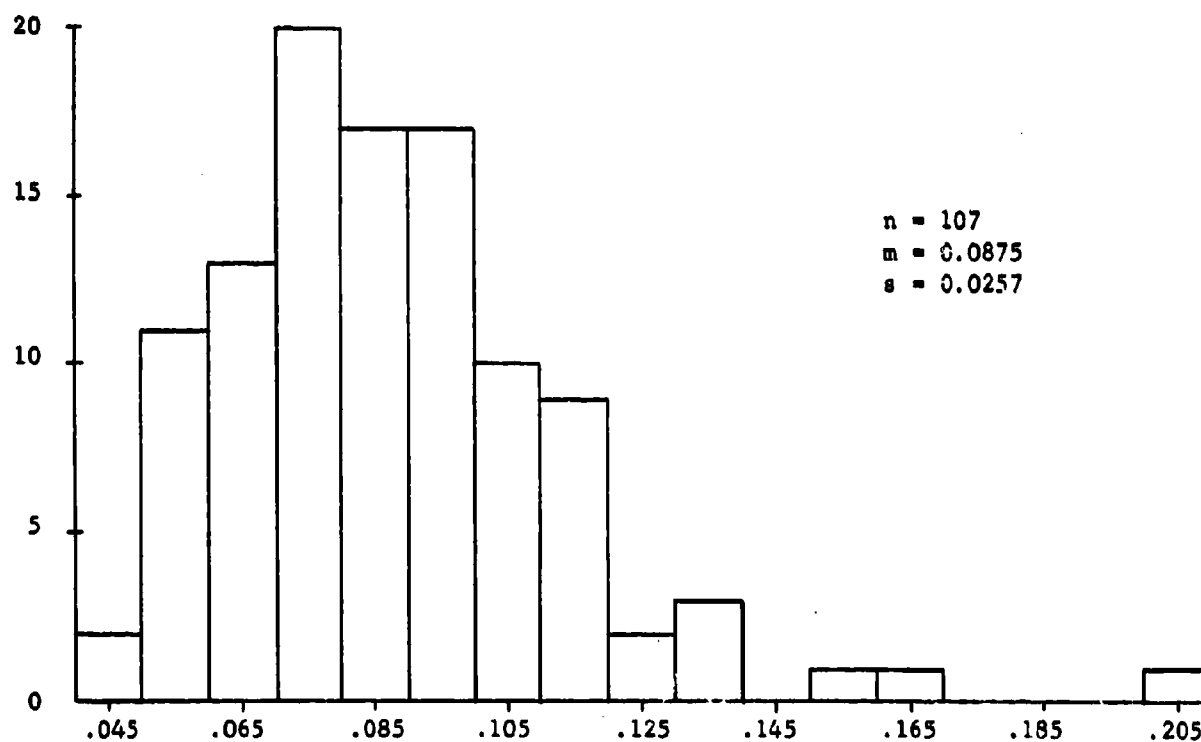


Figure 25. Frequency distribution of sample terrain unit slope numbers, Ranger training areas, Fort Benning, Georgia.

on Plate 6. Slope values are graphed in Figure 25.

G. Parallelism Number

The parallelism numbers, referred to as Q-values, are so irregular in their distribution that they defy the fitting of any model from which a prediction interval can be determined; thus, there is no plate for these values. Figure 26 shows this irregularity graphically.

H. Determination of Terrain Unit Parameter Values

The individual terrain units in the Benning area were determined in much the same fashion as were those for the Dahlonge area. (See Part 1, pages 77-80.) The elongation and parallelism numbers were determined in the same manner as for the Dahlonge area. Strictly speaking the rays for obtaining the terrain unit values were not drawn in a random fashion; instead, an attempt was made to draw profile rays which would extend into the various irregularities of the individual unit. In most instances the selected rays yielded a percent difference for the last ray used that was 5% or less.

The slopes (θ-values) being the ratios of associated R and D-values were derived by using only the averaged unit R and D-values.

One disadvantage noted is that the set of rays which seem to best characterize the unit with respect to one parameter may not be the best set for another parameter. Another disadvantage is the subjectivity;

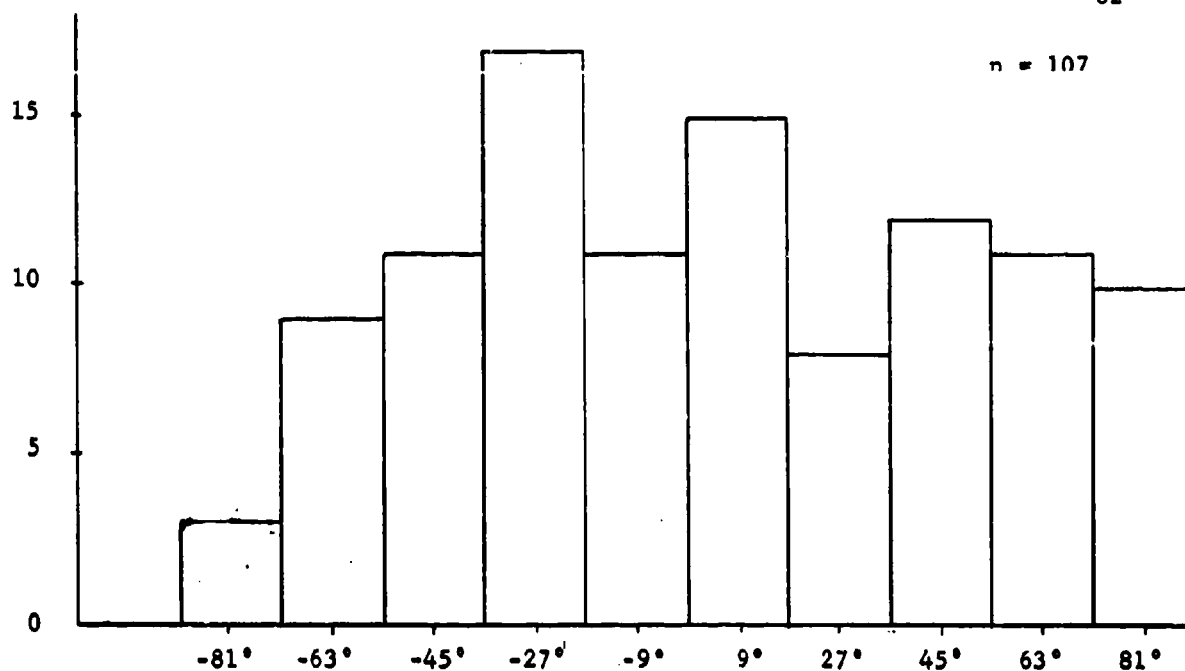


Figure 26A. Frequency distribution of sample terrain unit parallelism numbers (in degrees from north), Ranger training areas, Fort Benning, Georgia.

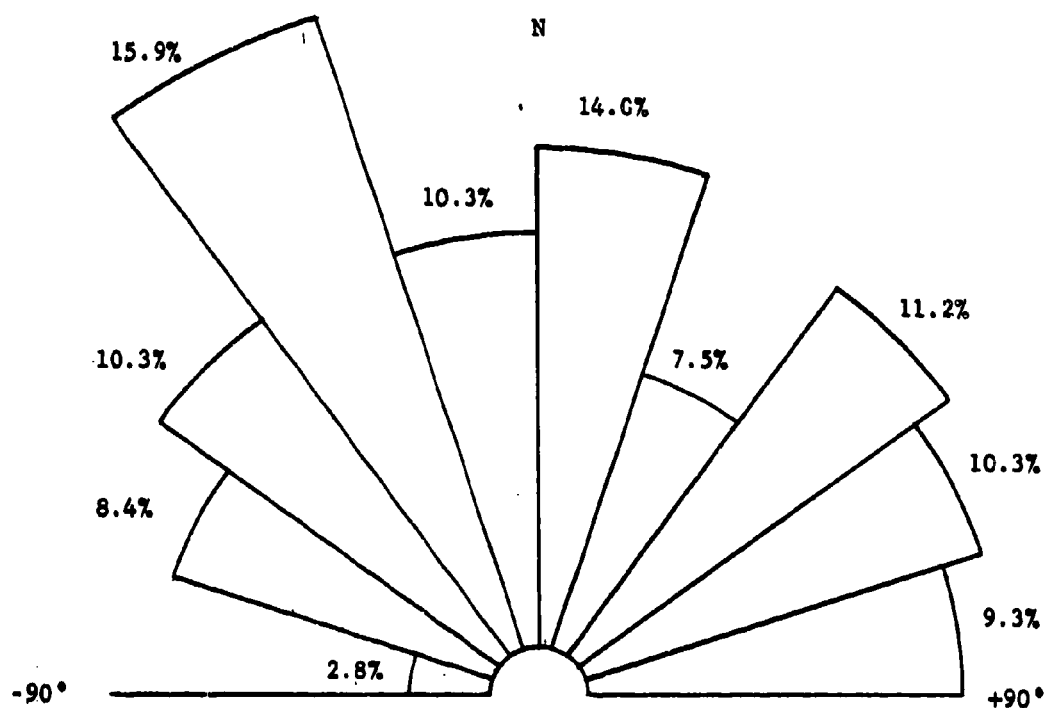


Figure 26B. Directional rose of sample terrain unit parallelism numbers (in degrees from north), Ranger training areas, Fort Benning, Georgia.

two different people may see the terrain unit differently. Overall, the most efficient method of selecting rays is probably random selection provided that the people doing the job understand the meaning of randomizing. It is also essential that some reliable randomising device be used faithfully.

IV. VEGETATION STUDY

A. Objectives

The major objectives were:

- (1) to continue a study of the physiognomic structure and organization of vegetation,
- (2) to record and report by means of the WES-standardized system of diagrams the variation in and among the several kinds of plant communities present,
- (3) to construct a map showing variations of the vegetation, accordingly as these might relate to military interests - especially those of the foot soldier.

B. Recent Vegetational History

The upland areas are covered with second-growth pine stands in a multitude of stages of condition. The steeper valley sides and more moist lowlands support a broadleaf vegetation consisting of several types.

It is difficult to read Harper's (1930) map, but he represents the area within his "Blue Marl" and "Sand Hills" natural regions and reports longleaf pine as having been the commonest tree of the Sand Hills and loblolly, longleaf, and shortleaf pines as being the most representative of the Blue Marl region.

Spillers and Eldridge (1943) include the area within the short-leaf-loblolly-hardwoods type on their map, and Braun (1950) includes it in her Gulf Slope section of the Oak-Pine Forest Region.

Walker and Perkins (1958) include the Cusseta and most of the Glen Alta areas in their loblolly pine type and show the northeastern portion of Glen Alta in an oak-pine category.

Both areas bear scars from extensive use by the military, and the Glen Alta portion is particularly "ragged and weedy" in aspect.

C. Methods

1. Introduction

The field work on these areas was done during the 1963 summer season, and nearly all procedures as described in the report (Part II) on Eglin Air Force Base, Florida, were continued.

2. Data Forms

Field data forms developed for use in the Eglin area (and illustrated in Eglin report) were used without modification.

3. Choice of Sampling Areas

Aerial photographs at scale of 1:20,000 showing ground conditions as of February 1957 were available and were used to locate areas for intensive ground study. It was immediately apparent that much of the vegetation was originally upland evergreen (pine) forest and that there was pattern to it, but questions such as actual stem size, how many other

types of plants were associated with the pines, and height classes of the plants forming the thickets had answers less obvious. Areas were eventually chosen for sampling to obtain data for these and similar questions, and to search for information which could be used for mapping purposes. Visual means were generally employed to locate samples within what appeared to be average vegetation for the site or type in question.

4. Sampling Procedure

Field sampling procedures were continued as described in the report on the Eglin area.

5. Mapping

Aerial photographs have yielded the principal body of information used for extrapolation from the limited number of field samples to the generalized vegetation map. Ground observations have also helped. Gross vegetation types particularly emphasizing the attributes of cover, height, and stem density as these might relate to military activity have been recognized under the heading of old field, thicket, savannah-woodland (lumped together), forest with thicket, forest without thicket, and slash. (A fuller description, with diagrams, is contained in the report on the Eglin area.) The category called slash includes the remaining vegetation of clear-cut or selectively cut-over sites where there are undecayed limbs or tops on the ground and where stump sprouts, poison ivy, and briars are often abundant. The type is

recognizable here with the same characteristics as at Dahlonega.

Graminoid, as a type, occurs only in areas too small to map, and steppe vegetation was not observed.

Construction of another type of map based on cover was attempted for the Cusseta area.

A plastic overlay marked with grid lines defining areas of one acre size at scale of 1:20,000 was constructed, and the aerial photos interpreted on a 100 percent basis. Using a prepared indicator (Moessner 1960), showing acre-size areas having known "cover" percentages, percents of cover for individual areas of the photographs were estimated by matching the indicator strip against the photograph. The problem here, of course, is that of recognizing an uppermost layer. Figure 27 is a map showing these estimations by means of a rating scale based on ten percent intervals.

Two kinds of readings were attempted - acre for acre (shown on bottom portion of the map), and estimates of four-acre squares using only the one-acre guide with the estimator doing his own extrapolation - shown by readings on upper portion of the map. Actual relation between the estimates and the precise cover values, however, are unknown (and these particular ones can never be checked because of seven years of changing ground conditions), but it is interesting that estimates made at a later interval for the same areas by the same observer may have a

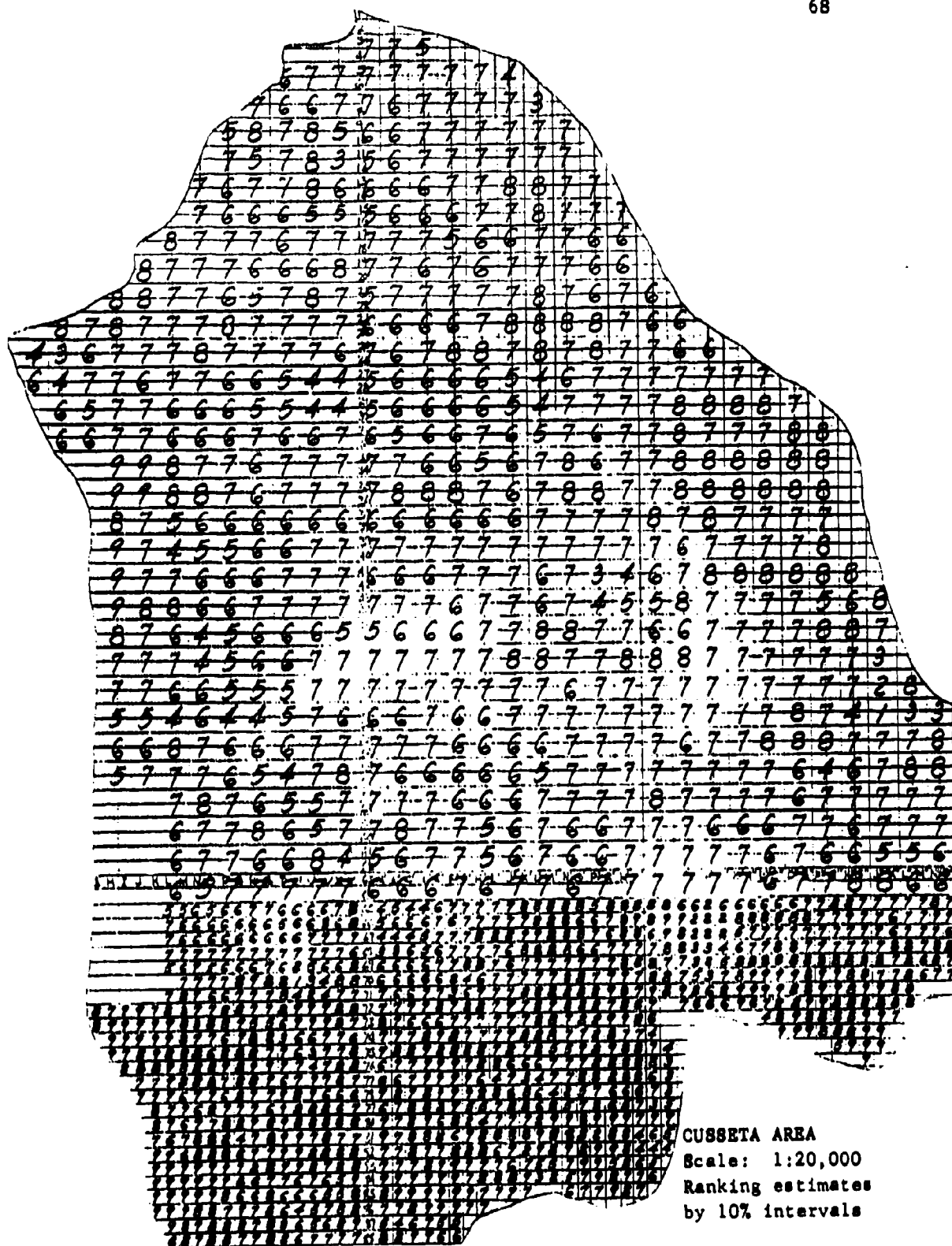


Figure 27. Cover map based on one-acre and four-acre readings.

fairly high correlation value. In one test, an area of 240 acres was estimated by one-acre units twice over a period of two weeks with a correlation between the readings of .875. In another test the same observer similarly estimated cover on a different 240-acre tract by four-acre units with correlation results of .675.

Detailed maps constructed in such a manner would always contain considerable error the degree being a function of the observer. But if smaller scale photos could be read by practiced estimators, strip transects in sufficient numbers might yield information useful for rapid determination of basic trends.

D. Results

Both areas are covered principally with a thin evergreen forest dominated by loblolly and shortleaf pines. Broad-leaved trees are associated with pine on lower valley slopes and are sometimes present in the valley bottoms in dense stands to the exclusion of pine. Low seepage areas support thickets chiefly of alder or mixtures of alder with red maple and sweetgum. Locally, on south- or west-facing dry knolls there are thickets composed of hawthorn.

Forty samples were obtained by the nested, variable-radius, circular plot method and their locations are shown on a map, Plate 8. Sample diameters ranged from five to fifty meters and the median was thirty. Samples with diameter of 20 meters or less included repre-

representatives of each of the mapping types, but also most of the old field and both of the thicket samples. Samples with diameters of 40 or more meters included representatives of five of the six mapping types one of which was old field. The two largest diameter samples were in savanna-woodland which is not at all surprising.

Vegetation diagrams for all samples have been drawn and are submitted as separate sets, along with one copy of each of the original field tallies.

Figure 28 illustrates the variation in numbers of kinds of elements appearing in the diagrams of the vegetation. The range among all samples is 5-25 and the median sample has 19.

The same figure permits comparisons as to relative complexity within the vegetation mapping types. The samples from old fields generally include the fewer numbers of structural elements, and forest with thicket the most. Thicket and slash are really wide in their ranges, a fact to be expected in the case of thicket since the samples were very different as to both species and habitat.

Distribution of the six vegetation categories and of land that is barren (?) of plants is shown for both areas at scale of 1:20,000 on Plate 7. No attempt has been made to distinguish among the associations within the forest or other categories. It should be noted, perhaps, that here as in the Eglin area the boundary between savanna-woodland and forest

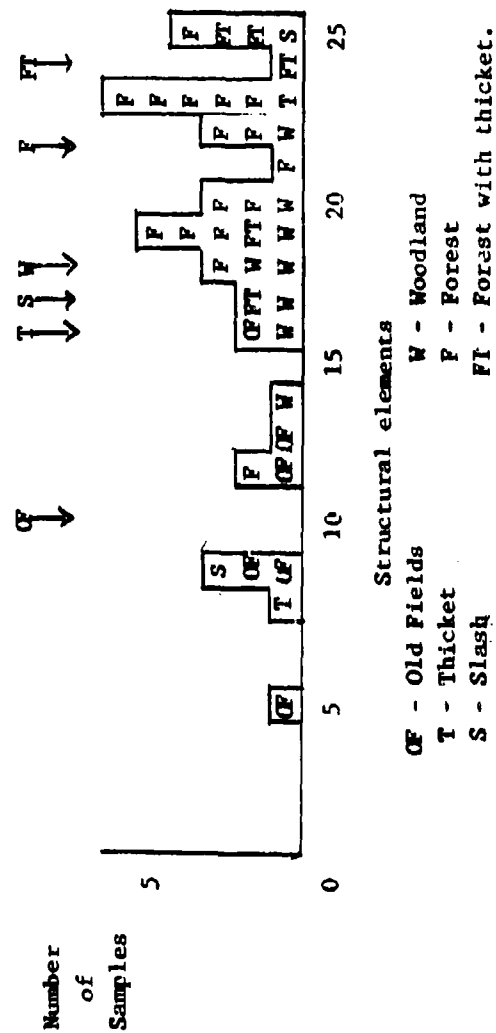


Figure 28. Variation in numbers of structural elements per sample in differing vegetation types.
Position of median is shown above.

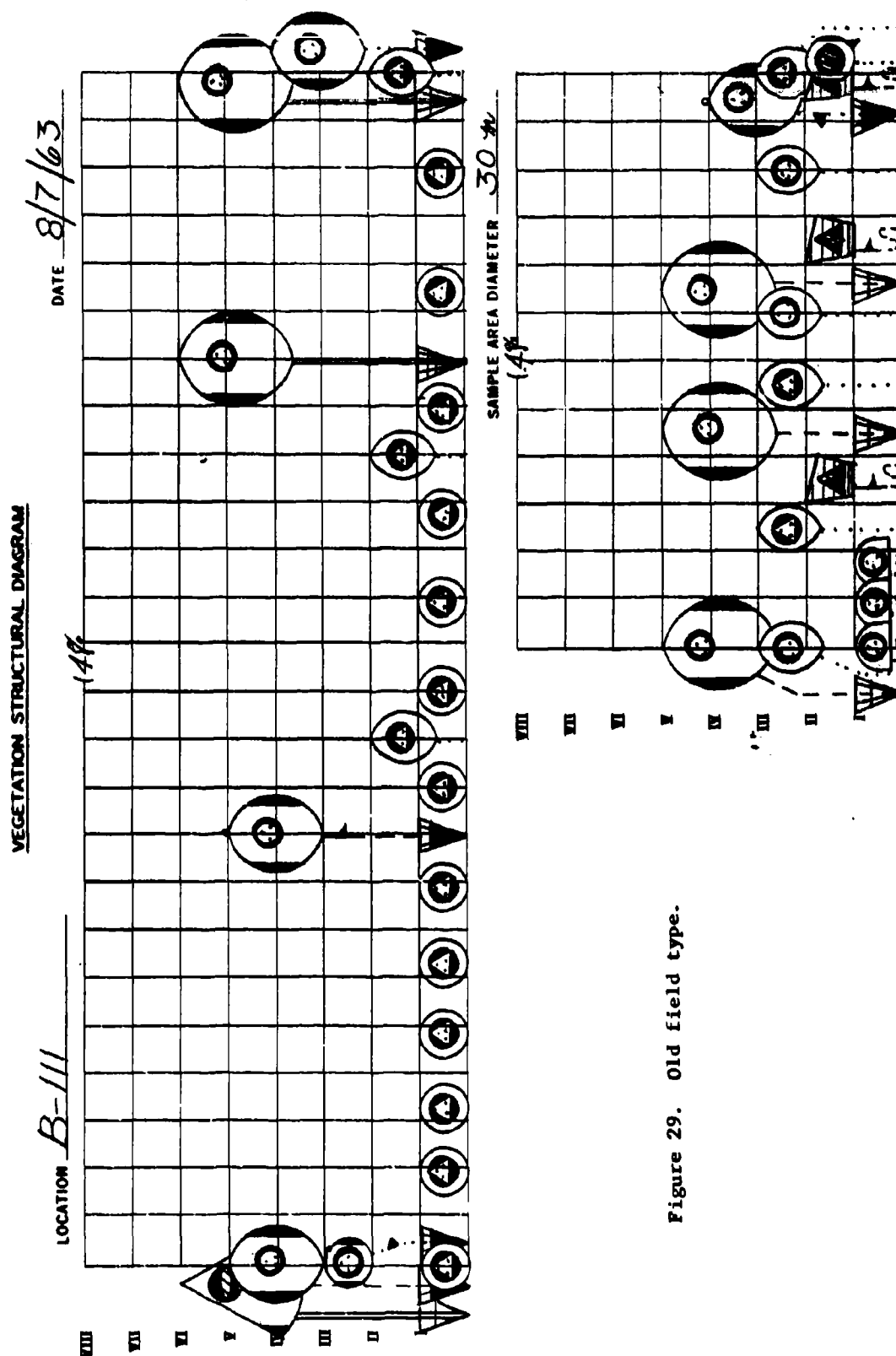
is a point in a graded series of overstories and is difficult to discern from aerial photos. The additional characteristics of degree of openness in lower height classes becomes more and more difficult to see as the overstory increases in cover. The line of demarcation used here was 50% overstory cover.

Diagrams and photographs illustrating the mapping unit categories are shown in Figures 29-41.

B. Analysis and Discussion

Average cover by height class is shown for each of the six vegetation mapping types in Figures 42-47 and ranges of the cover are shown in Figures 48-51.

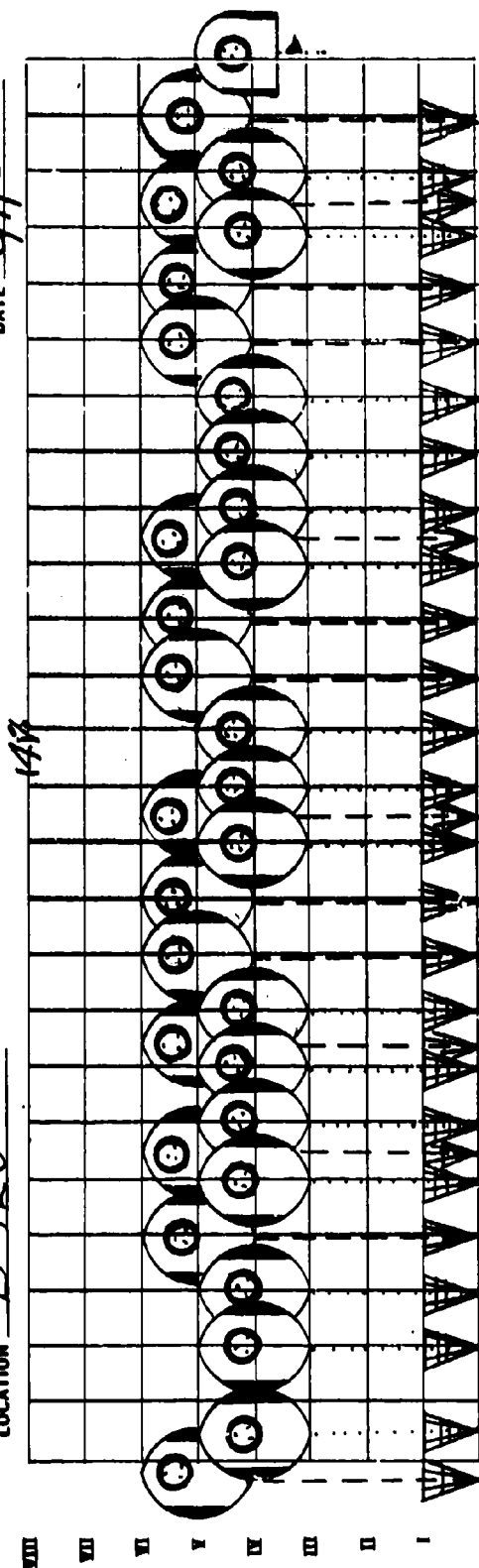
The uplands are covered chiefly with a forest of pine including both loblolly and shortleaf. Longleaf pines are locally present but are not abundant. In both areas, especially at Glen Alta, broad-leaved trees (upland oak species) are mixed in with the pines in the higher reaches of the ravines and on the north-facing slopes. In these communities the oaks are as tall or taller than the pines and differentiation into a two-tiered overstory such as was present on the uplands of the Eglin area is lacking. The broadleaf trees are of different species and are more like those of the Dahlonga area. All of the forests are intermediate in height and no vegetation in height class eight has been



VEGETATION STRUCTURAL DIAGRAM

LOCATION B-120

DATE 8/9/63



SAMPLE AREA DIAMETER 5m

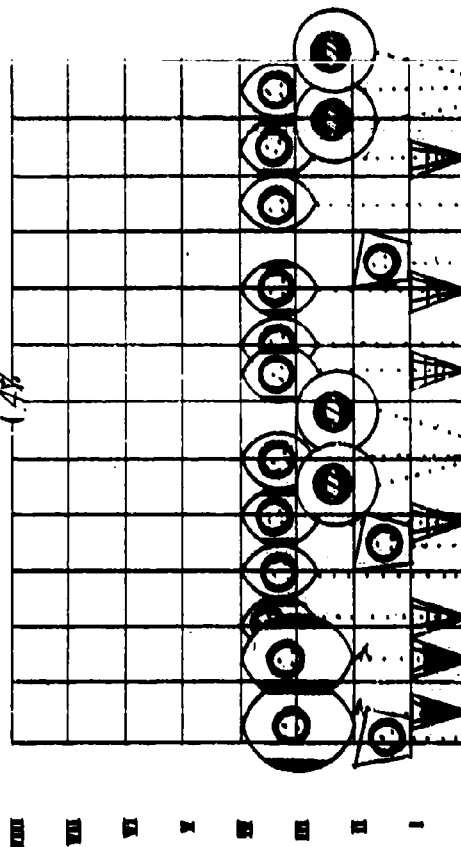


Figure 30. Alder thicket.

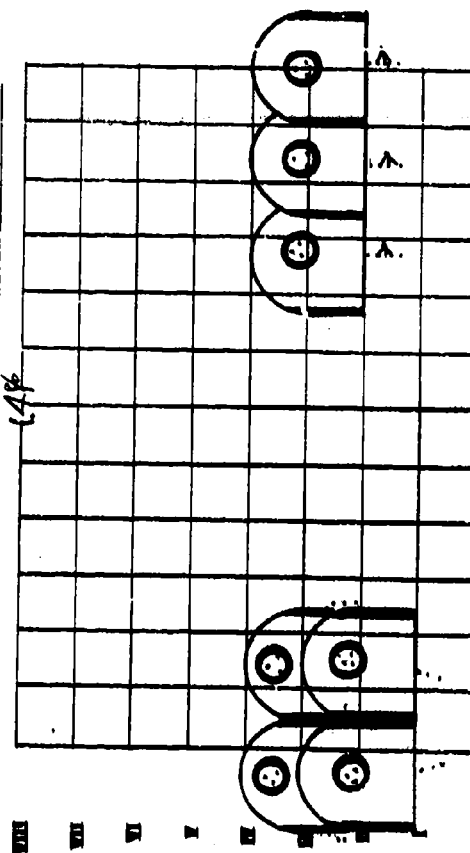
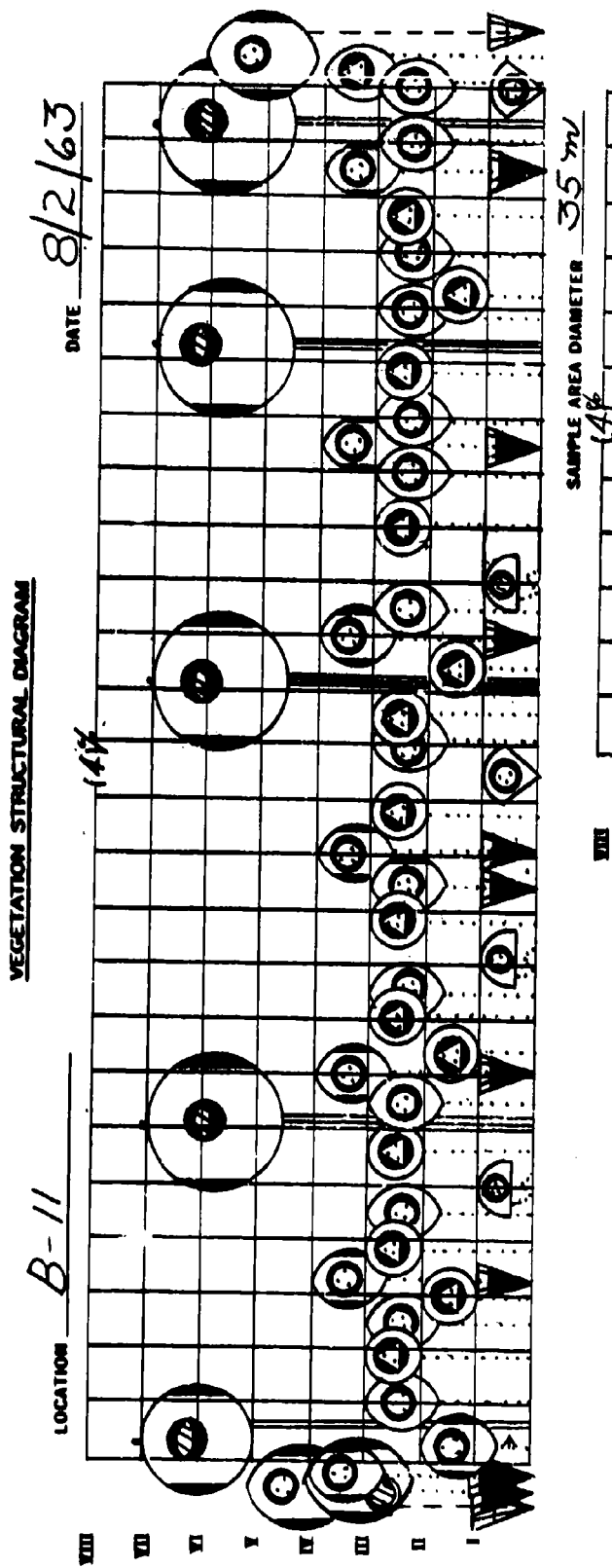
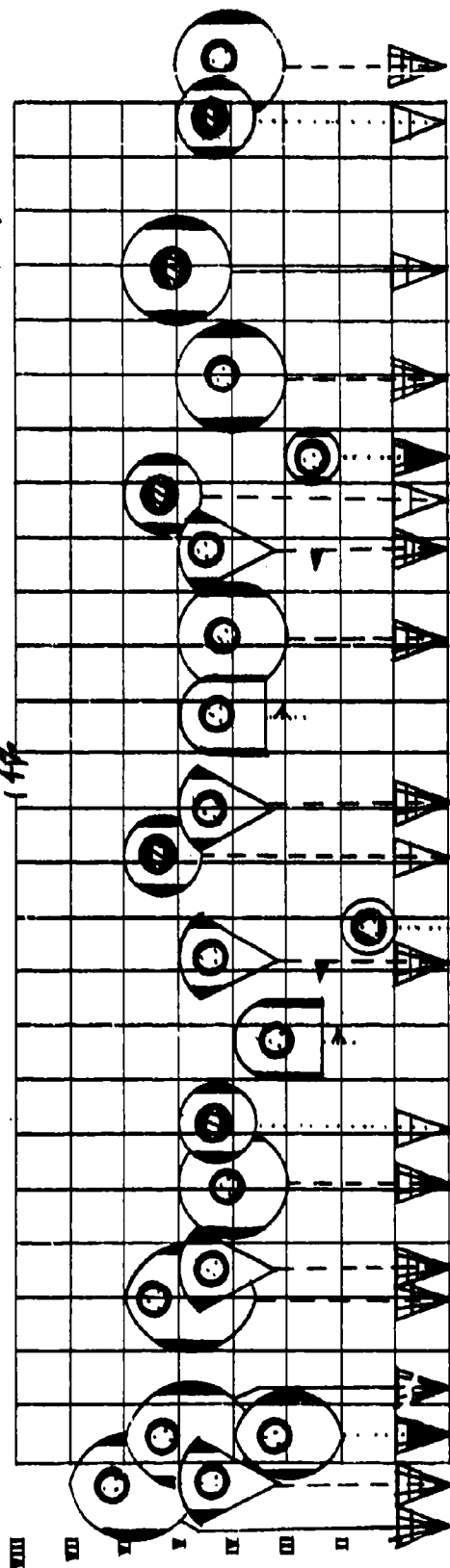


Figure 31. Savanna-woodland.

VEGETATION STRUCTURAL DIAGRAM

LOCATION B-15 - 1 of 2

DATE 8/3/63



SAMPLE AREA DIAMETER 30 m

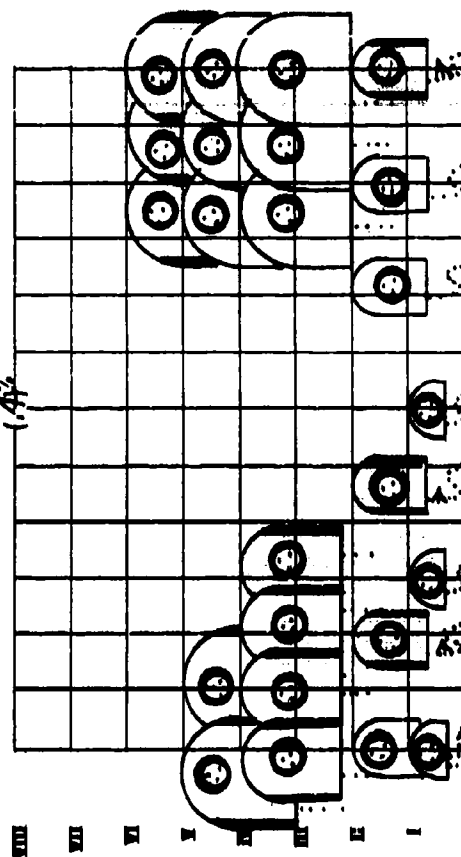
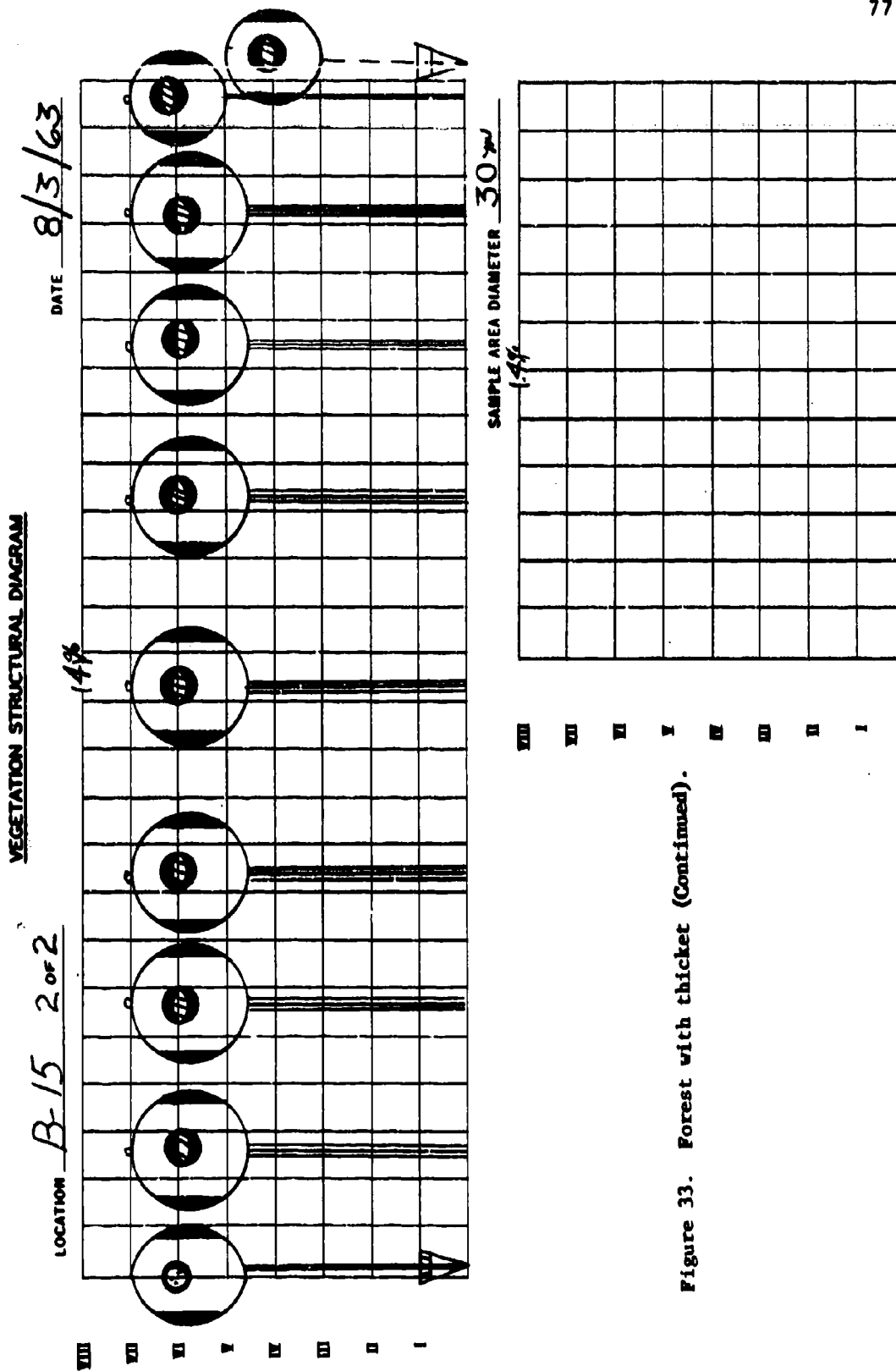


Figure 32. Forest with thicket.



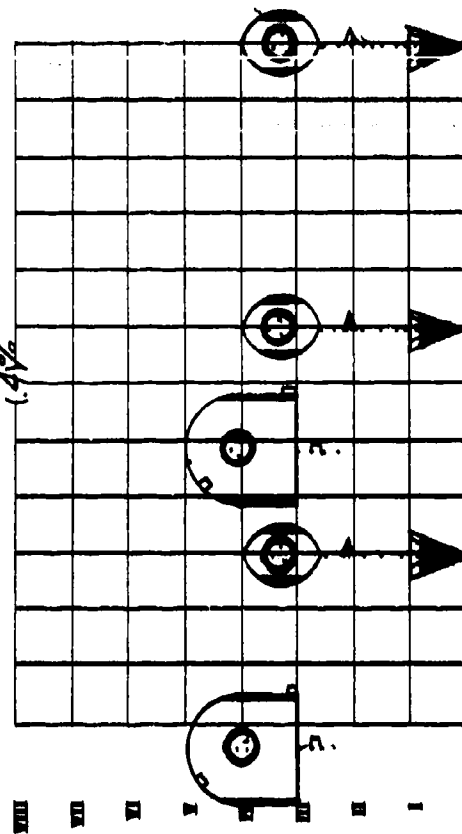
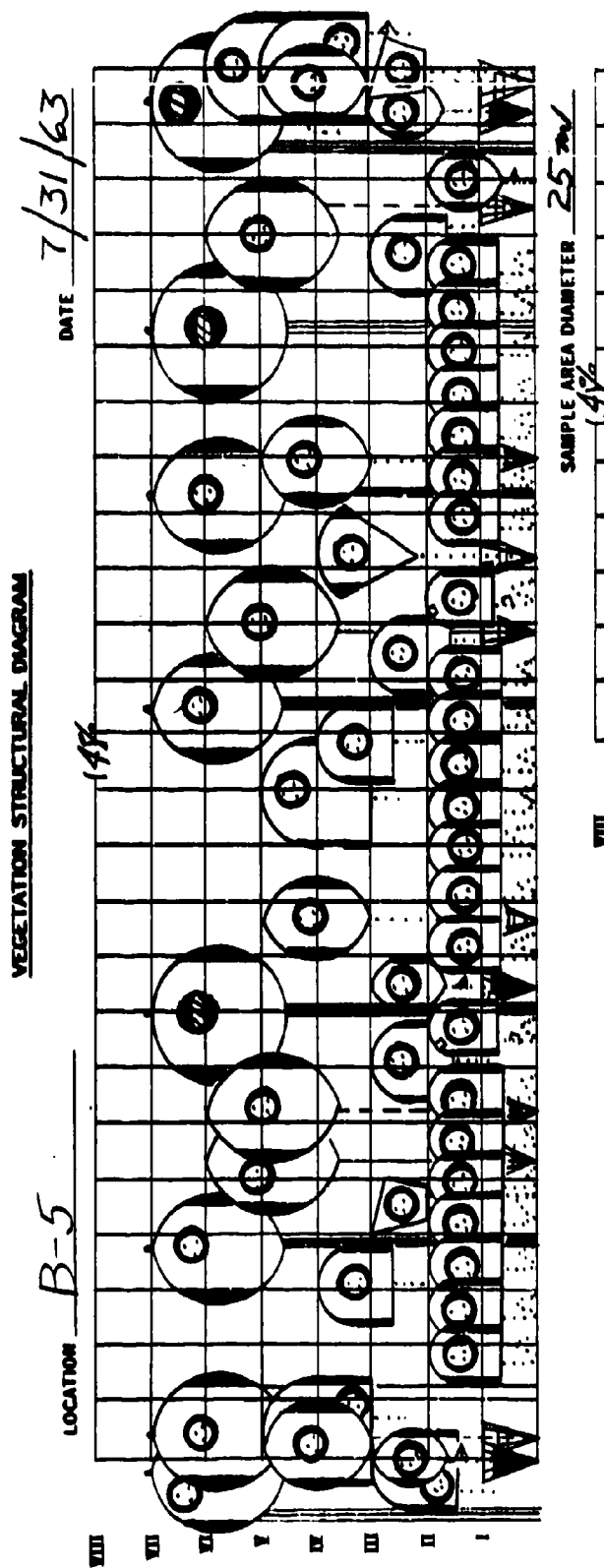


Figure 34. Forest without thicket.

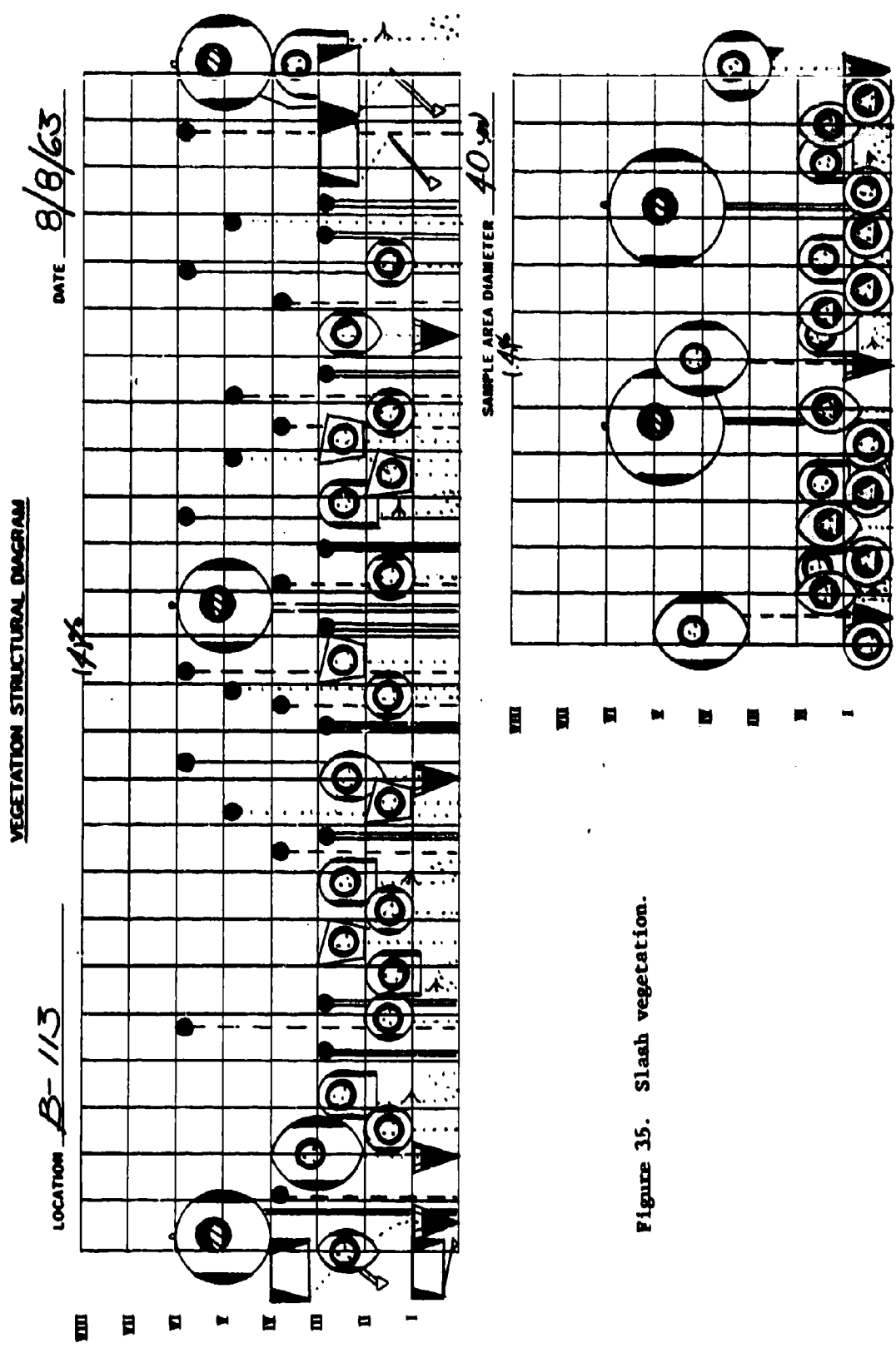




Figure 36. Old field vegetation consisting of broom-sedge, grass, rough herbs, and persimmon seedlings.

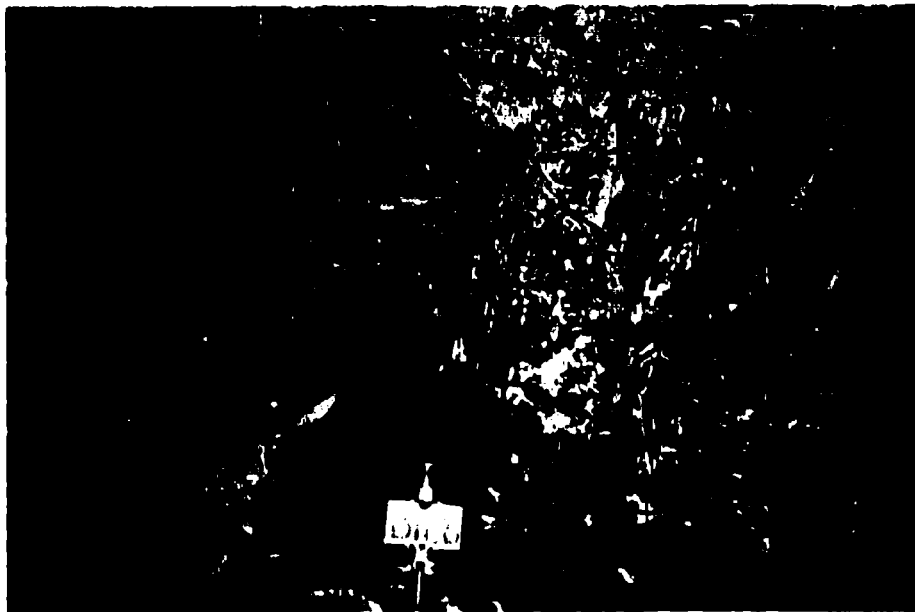


Figure 37. Interior of an alder thicket.



Figure 38. Shortleaf pine woodland with 56 percent cover by grasses in height classes two and three.

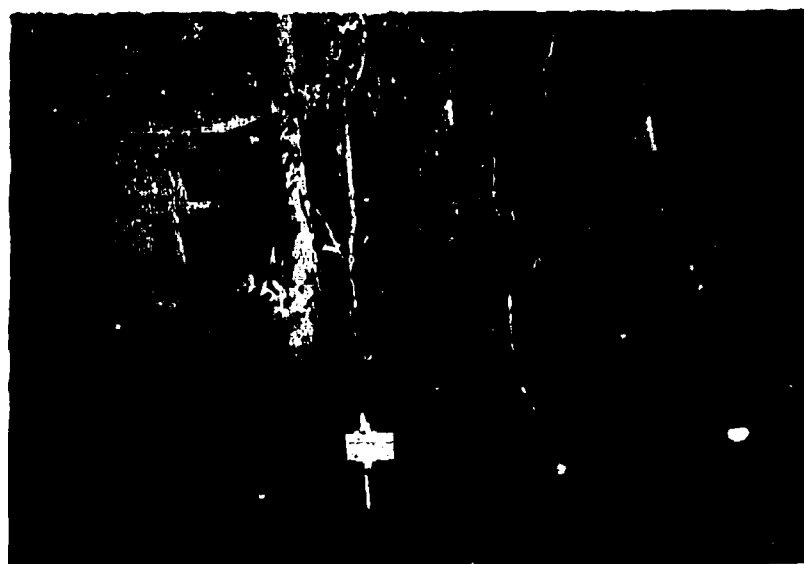


Figure 39. Forest with thicker. Variation in classes of stem sizes is prominent.



Figure 40. Shortleaf pine forest with abundant reproduction by the broadleaf species also present.



Figure 41. Slashed area of former longleaf pine forest.

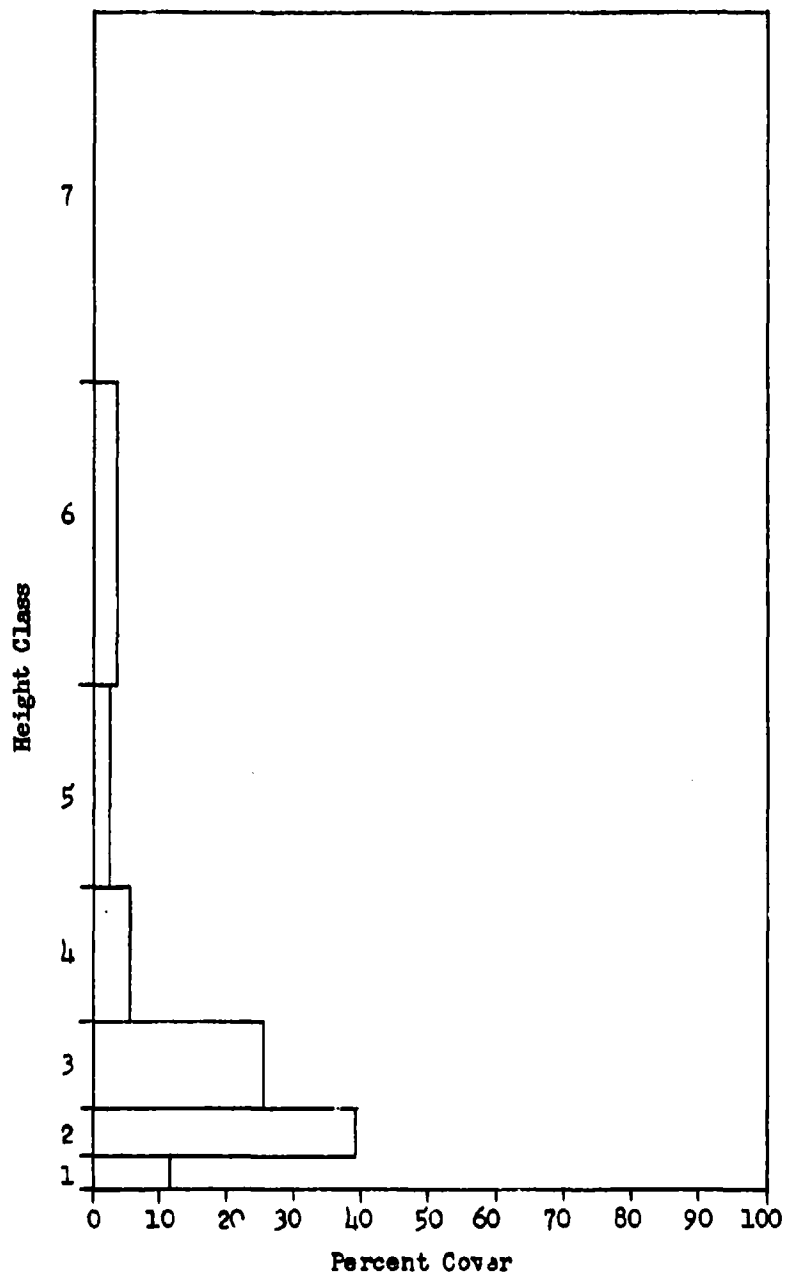


Figure 42. Average cover stratification in six samples of old field vegetation.

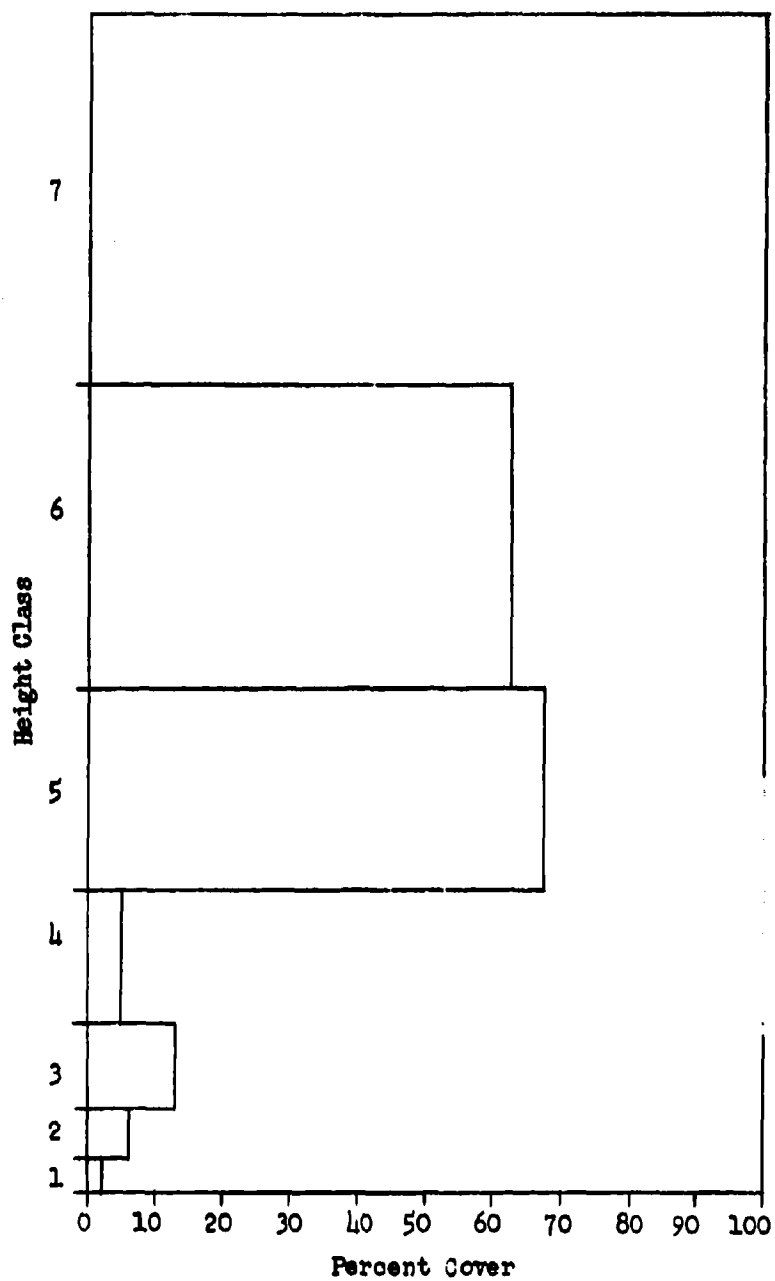


Figure 43. Average cover stratification of two samples of thicket.

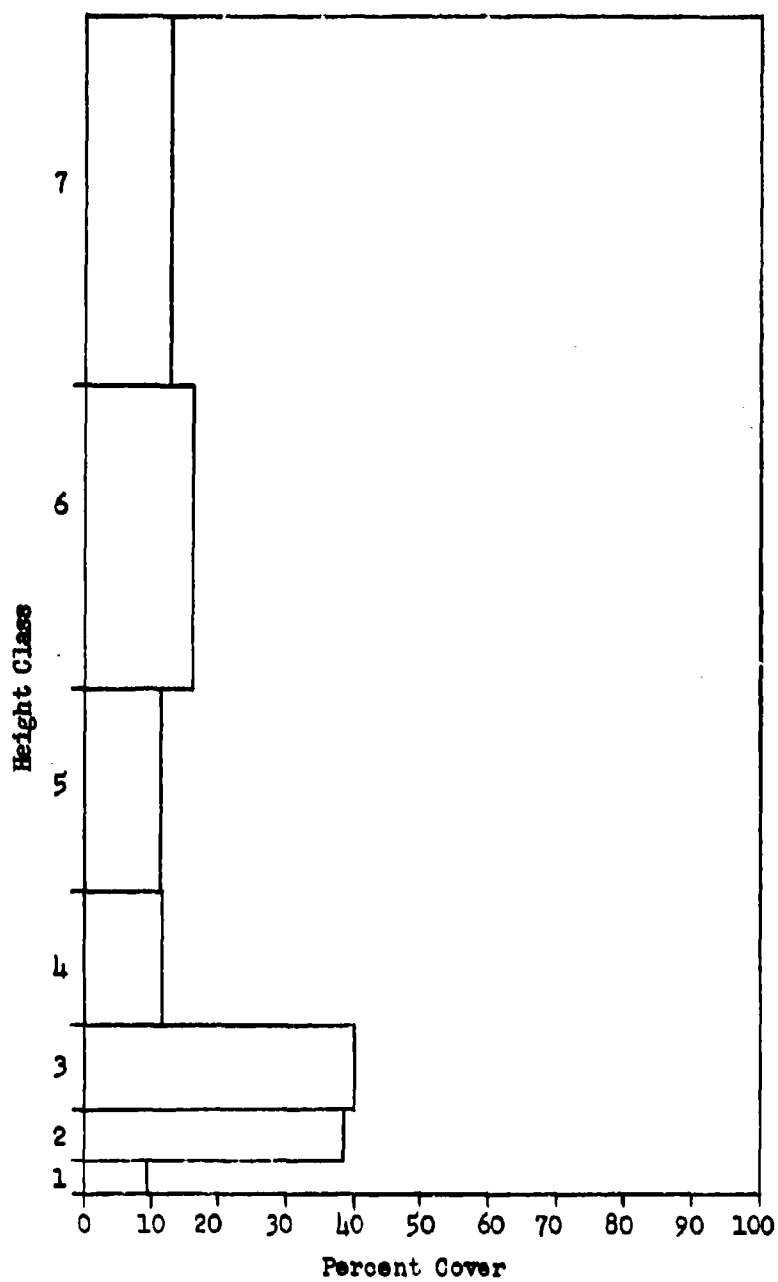


Figure 44. Average cover stratification in eight samples of savanna-woodland.

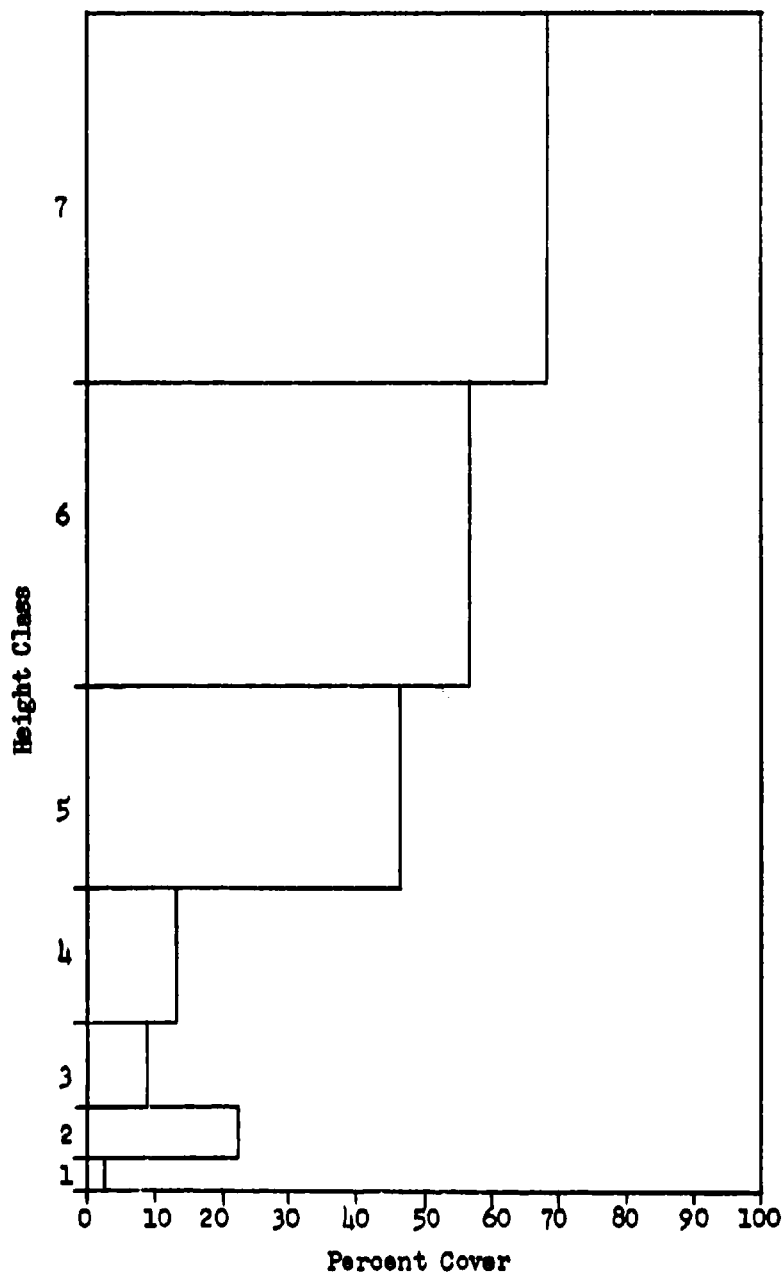


Figure 45. Average cover stratification in five samples of forest with thickets understory.

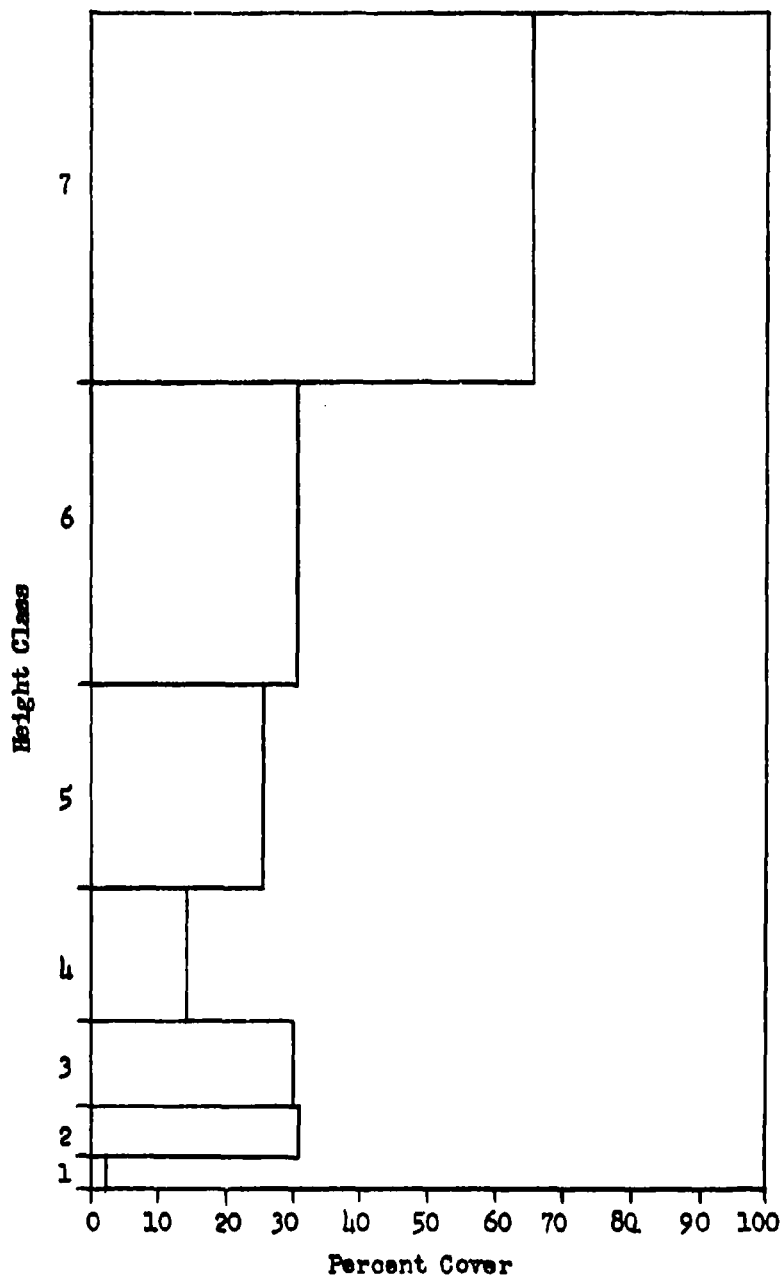


Figure 46. Average cover stratification in sixteen samples of forest.

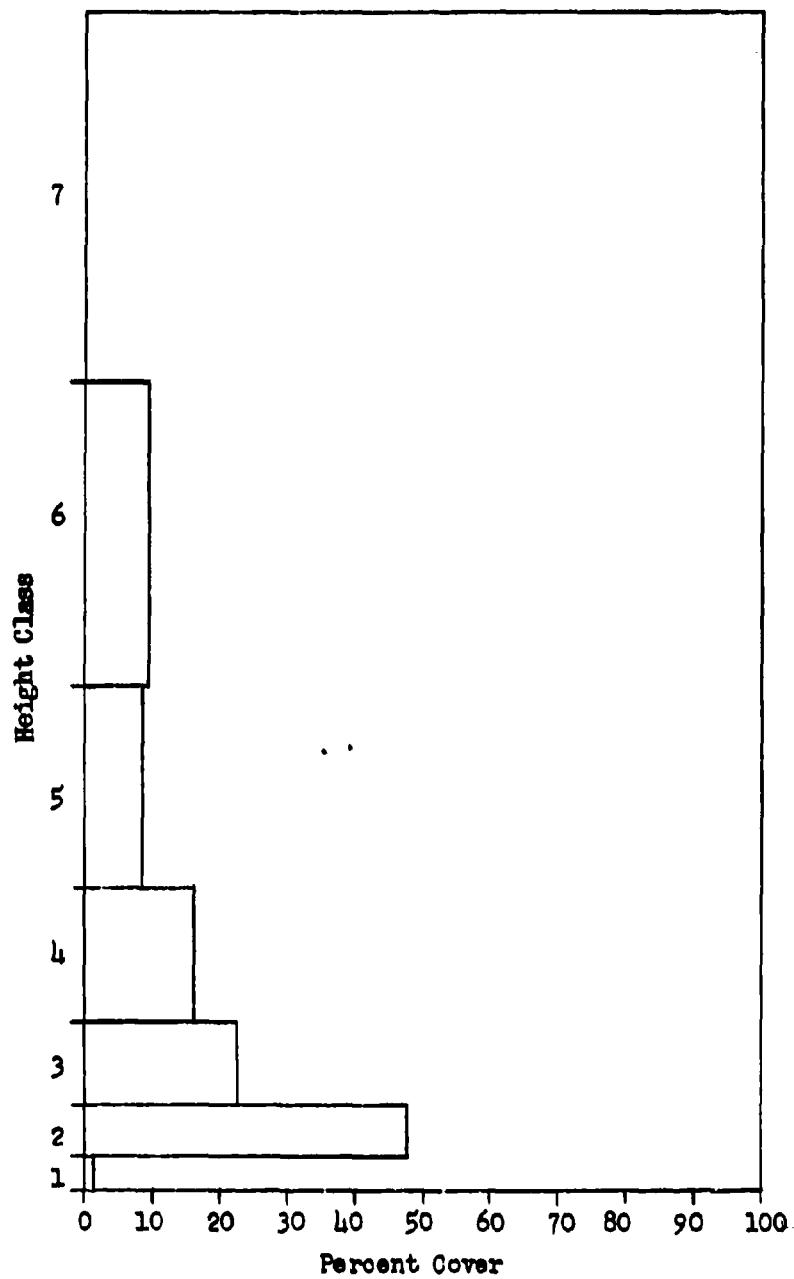


Figure 47. Average cover stratification in two samples of slash vegetation.

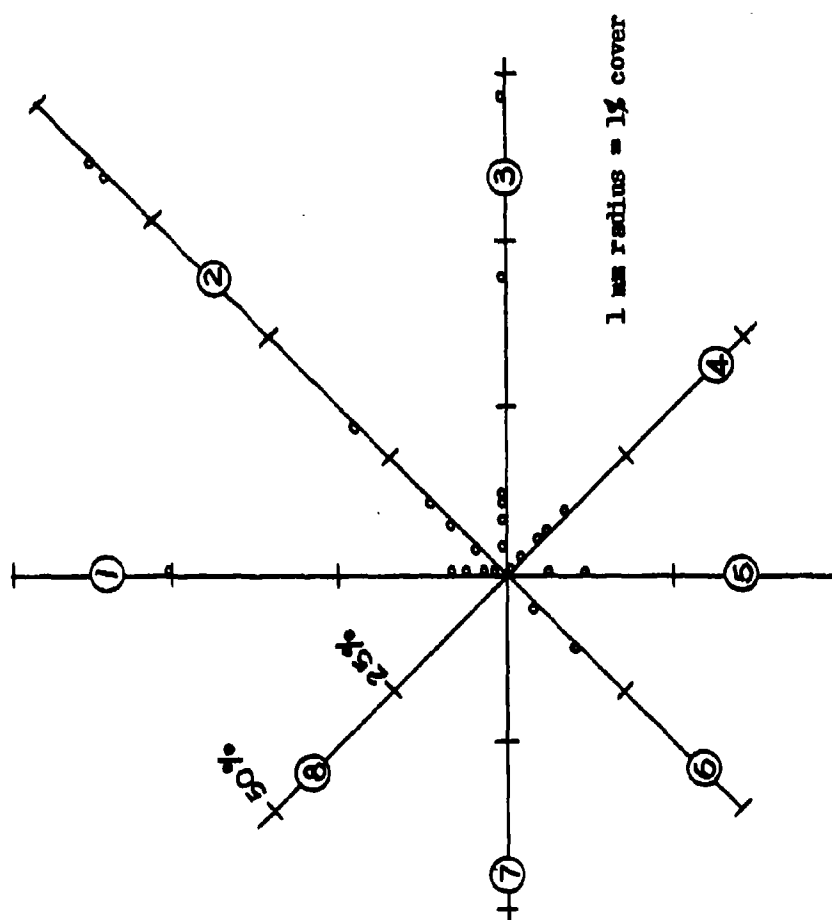


Figure 48. Ranges of cover by height classes in six samples of old field vegetation.

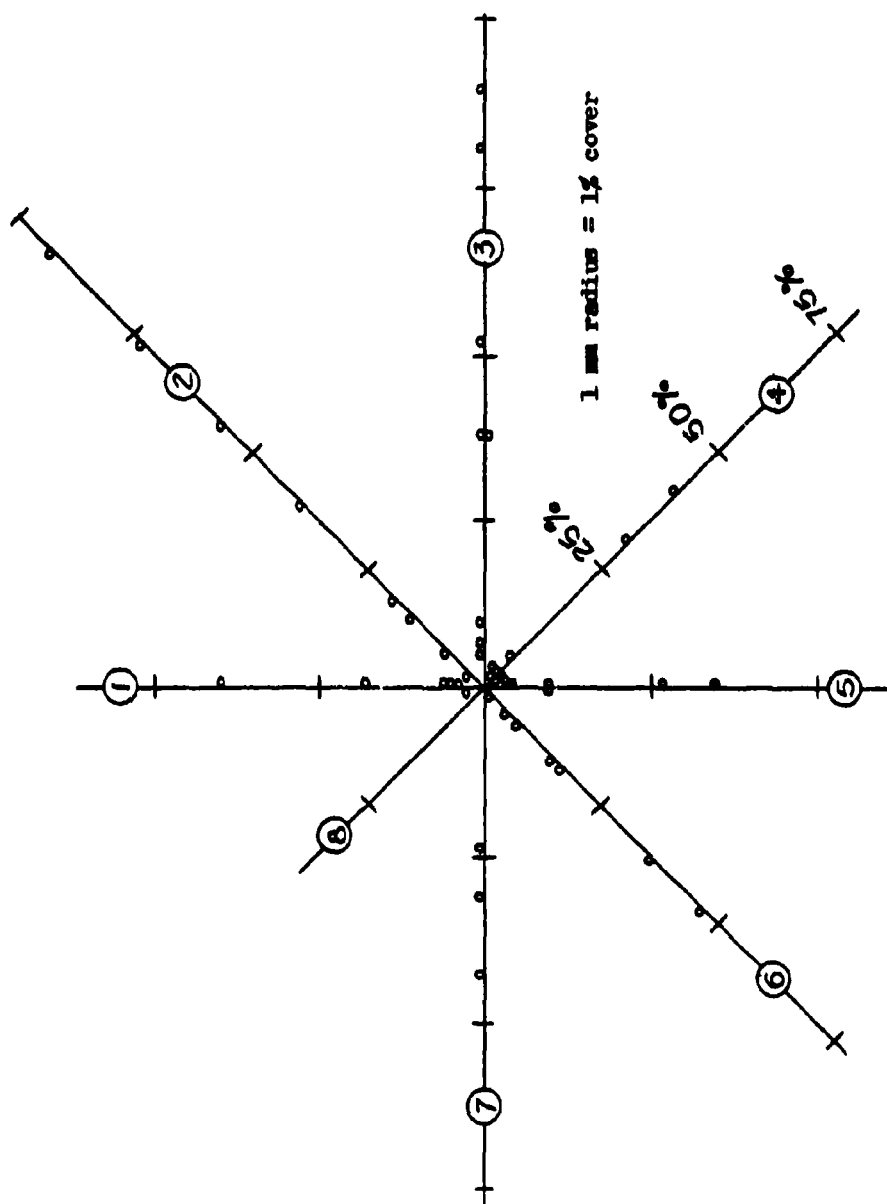


Figure 49. Ranges of cover by height classes in eight samples of woodland.

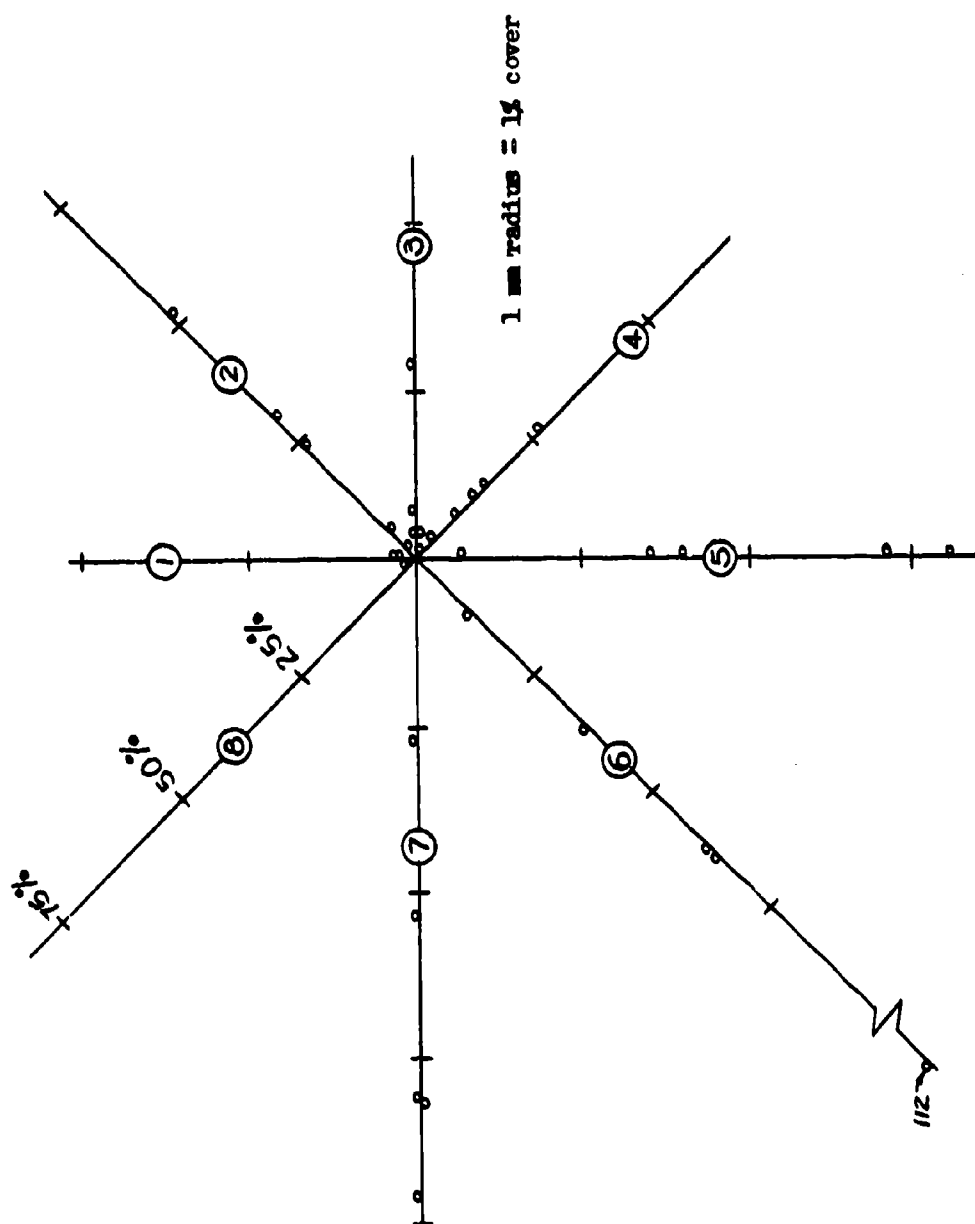


Figure 50. Ranges of cover by height classes in five samples of forest with thicket.

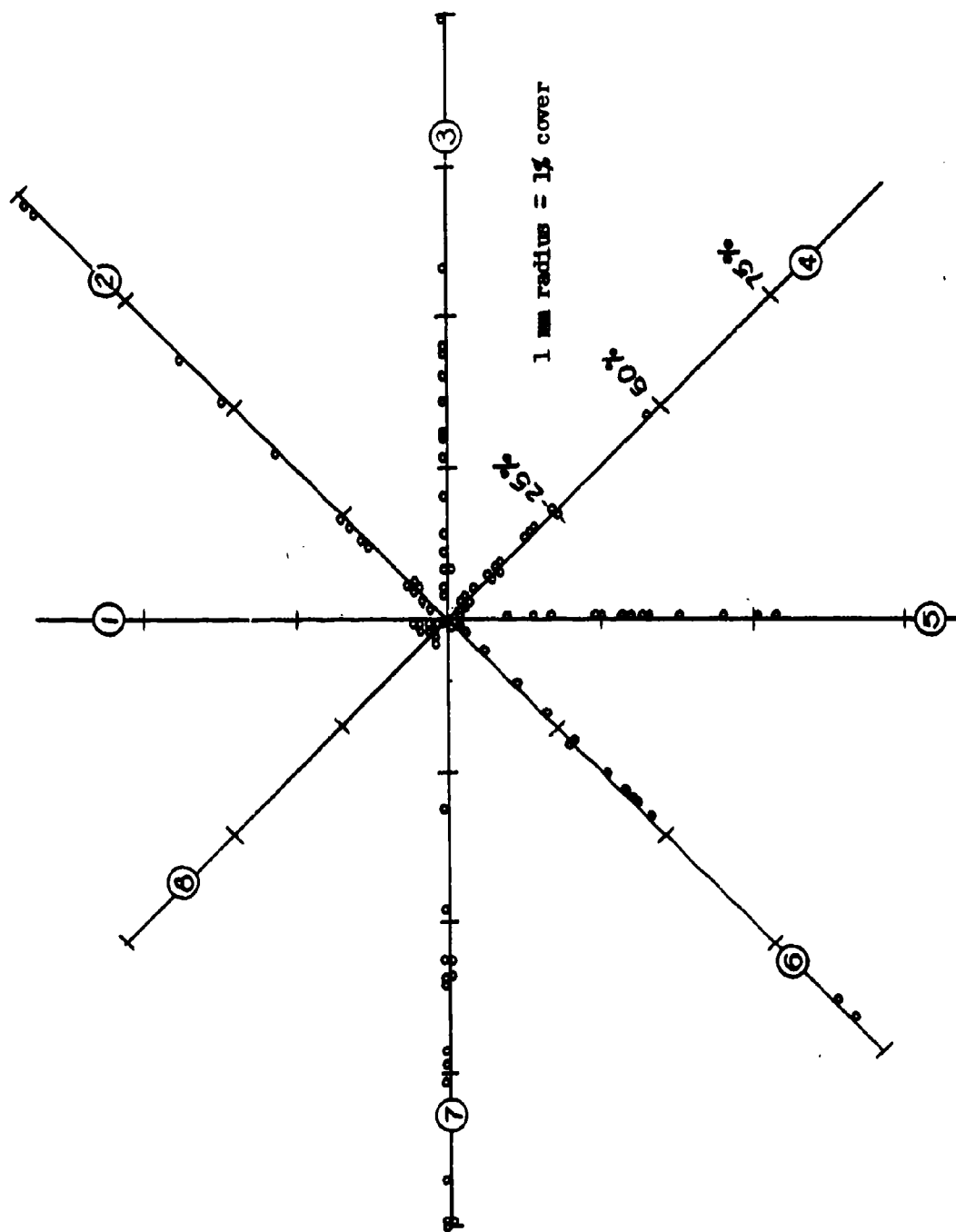


Figure 51. Ranges of cover by height classes in sixteen samples of forest.

recorded.

In the valleys of the larger streams thickets are locally present and are surrounded by a deciduous swamp forest. The thickets are composed of dense, nearly pure stands of height classes five and six alder or of alder mixed with other small tree species. The swamp forests in their wettest phases include many of these same thicket forming species in high abundance but under an overstory and comprise the vegetation mapped as forest with thicket. The thicket includes a number of evergreen species and alder is often sparse. Swamp forests of the less wet lowlands lack the woody thicket understory and have lower strata rich with deciduous herbs and vines.

Another distinctive type of thicket occurs locally on the upland and consists of a dense orchard-like aggregation of hawthorn trees. Isolated hawthorns are common in old fields on the dry, southerly-facing leads, but where they occur in stands of high density with a mean area per individual of 2.4 sq. meters, and stems of 7.5-15 cm. diameter have a mean nearest neighbor distance of .70 meters they constitute a formidable obstacle to passage.

Reed-like growth occurs about both Weems and Schley Ponds, and there are prairie-like remnants of grassy turf scattered about in the shelled (impact) areas but these graminoid vegetation patches are too small to map.

As mentioned in the Eglin report, some quantitative aspects of distribution of data from both Eglin and Benning areas have been treated similarly and are discussed here together.

An examination of stem distribution is of interest.

In a vast majority of samples trees were the dominant plants and were used as determinants in estimating appropriate sizes of samples. In keeping with the structural cell concept, single samples should be large enough to include the basic pattern of dispersion of the determinant structural elements and theoretically need be no larger. Non-determinant plants would be over or undersampled accordingly as their own variety of distribution related to the sample size used. A central problem then has been to arrive at a means for discovering and expressing the measure of dispersion at hand. Data available from field sampling included plane table maps showing positions of determinant stems, their diameters, and in most cases, their crowns. The maps have been useful for determining distances to nearest neighbors, and for studying relationships among the subsamples formed by the application of suitably marked overlays.

With reference to the works of Moore (1954), Evans and Clark (1954), and Miller and Kahn (1962), interrelationships and concepts relative to randomness of distribution in populations and degree of departure from this randomness can be developed and applied to the data in the present case as follows.

Consider a large number of points, say 1,000 or more, distributed randomly over a large plane area. (A forested surface of sufficient size might constitute such area of applied interest.) The probability that a randomly chosen sample area of given size taken from a plane containing a random distribution of points will contain exactly s points is, by the Poisson model, $(m^s e^{-m}) (s!)^{-1}$; m is the mean density per sample area. If D is the average population density per unit of area, then $m = D\pi r^2$ is the average number of points per sample area for all circular areas of given radius r . Substituting in the Poisson model $P(s) = (D\pi r^2)^s e^{-D\pi r^2} (s!)^{-1}$ is the probability of finding exactly s points in the circular area. The probability that such an area as πr^2 units will contain no points is given by $e^{-D\pi r^2}$. If the sample area is centered on some randomly chosen point, the probability that no other point will be found within some distance r will also be given by $e^{-D\pi r^2}$. The probability of finding no points within a given area plus the probability of finding one or more points within the same area is equal to one, for one event or the other is certain to occur. Thus the probability of finding one or more points at a distance less than or equal to r is $1 - e^{-D\pi r^2}$, and this is the proportion of distances to nearest neighbor equal to or less than r ; that is,

$$P(r) = 1 - e^{-D\pi r^2}.$$

Upon differentiating, the probability distribution (Figure 52) of r

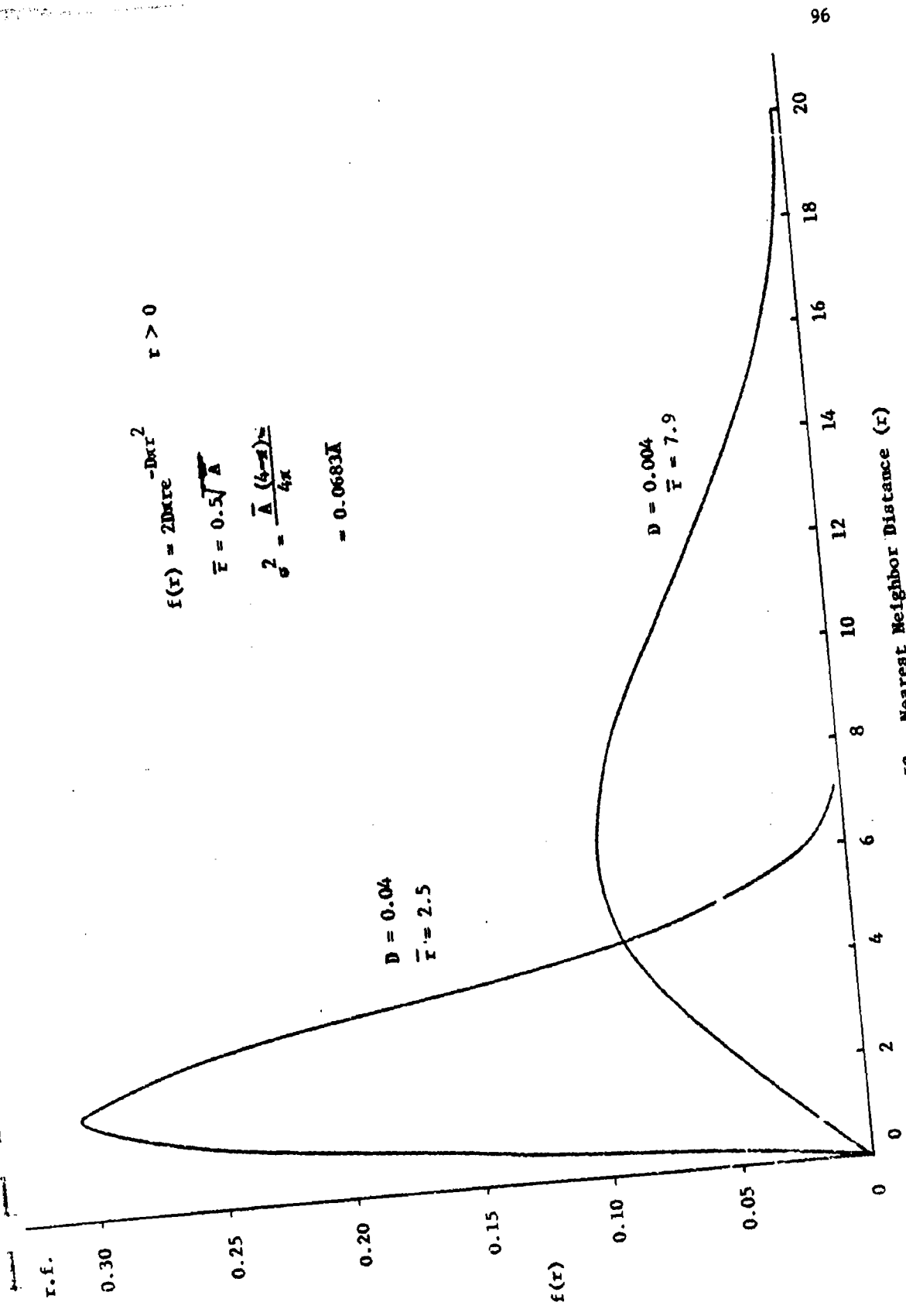


Figure 52. Nearest Neighbor Distance (r)

is obtained:

$$g(r)dr = dP(r) = 2D\pi r e^{-D\pi r^2} dr.$$

The expected value of r , i.e., $E(r)$, is the mean of r , denoted by \bar{r} ; and it may be determined by applying the general expression

$$E(r) = \int_0^{\infty} r g(r) dr, \text{ i.e.,}$$

$$\begin{aligned} r &= \int_0^{\infty} 2D\pi r^2 e^{-D\pi r^2} dr \\ &= \pi D \int_0^{\infty} r e^{-D\pi r^2} 2r dr \end{aligned}$$

which is in the form (Selby, 1962, p. 317)

$$C \int_0^{\infty} x^n e^{-nx\sqrt{x}} dx = C \left[\frac{1}{2n} \sqrt{\frac{\pi}{n}} \right],$$

$$\text{thus, } \bar{r} = \pi D \left[\frac{1}{2\pi D} \sqrt{\frac{\pi}{\pi D}} \right];$$

and simplified,

$$r = \frac{1}{2\sqrt{D}}$$

Since D is the average population density per unit of area, the mean area per individual, \bar{A} , is equal to D^{-1} . Upon substitution,

$$r = 0.5\sqrt{\bar{A}}.$$

It can also be shown that the variance of this distribution is equal

to $\bar{A} (4-\pi)/4\pi$ which is approximately equal to $0.0683\bar{A}$.

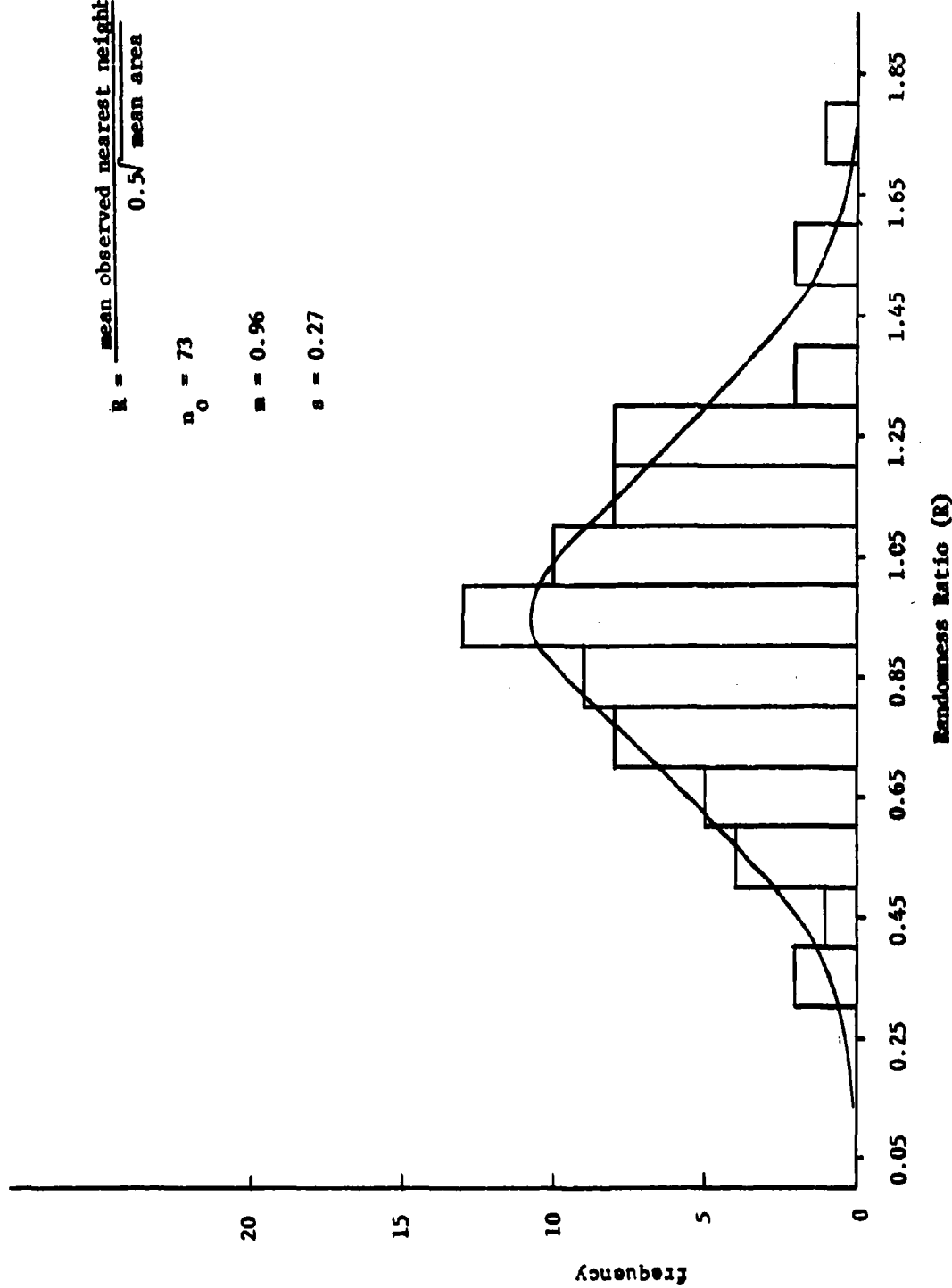
Inasmuch as the relationship $\bar{r} = 0.5\sqrt{\bar{A}}$ is based upon the properties of a random distribution it follows that the resulting value might be compared with a field determined value in order to obtain some judgement as to the degree of randomness of the field population. It can be shown that such a ratio has upper and lower boundaries of zero and 2.149 respectively. A low ratio, R-value, indicates clustering and a high R-value indicates a tendency toward a hexagonal pattern. Figures 53 and 54 show the distributions of the randomness ratios for 73 sample areas from the Eglin and Benning areas. (Though the R-values of Figure 53 appear to be normally distributed, it is entirely possible that as the population mean shifts to either extreme the distribution becomes distinctly asymmetrical.) From the relationship

$$R = \frac{\text{mean observed nearest neighbor distance}}{0.5\sqrt{\text{mean area}}} = \frac{\bar{D}}{d},$$

it can be seen that the mean observed nearest neighbor distance is R times that distance expected in a randomly distributed population.

Figures 55, 56, and 57 illustrate clustered, random, and "regular" distributions respectively of points as indicated by the R-values of 0.357, 1.037, and 1.310.

It should be noted that a population of interest exists only as defined. The stem distribution diagrams of Figures 55, 56, and 57



$$R = \frac{\text{mean observed nearest neighbor distance}}{0.5 \sqrt{\text{mean area}}}$$

$$n_0 = 73$$

$$m = 0.96$$

$$s = 0.27$$

Figure 53. Sampling Variation of Randomness Ratio ($n_1 + n_2 + n_3 + n_4 + n_5 = n_0$)

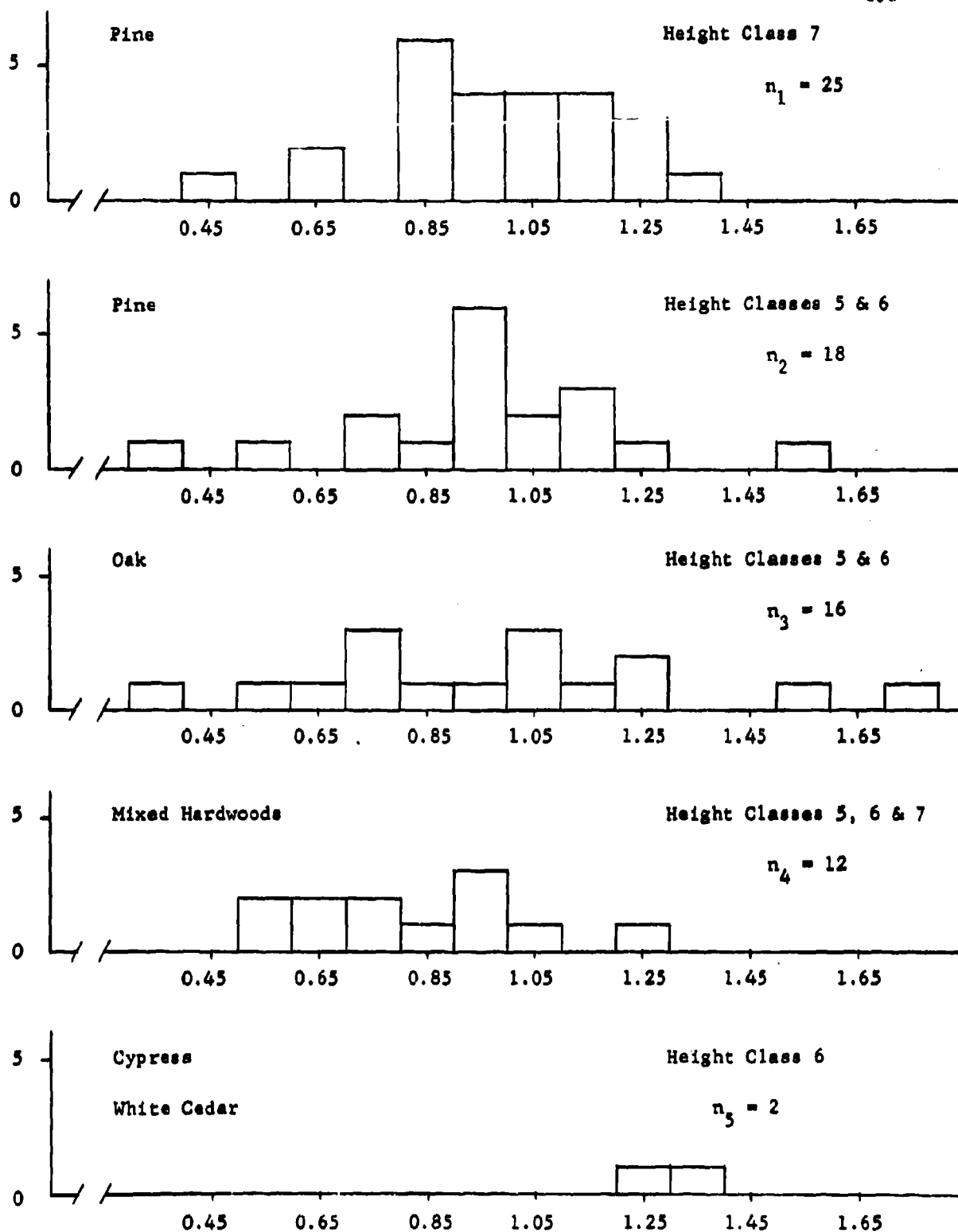
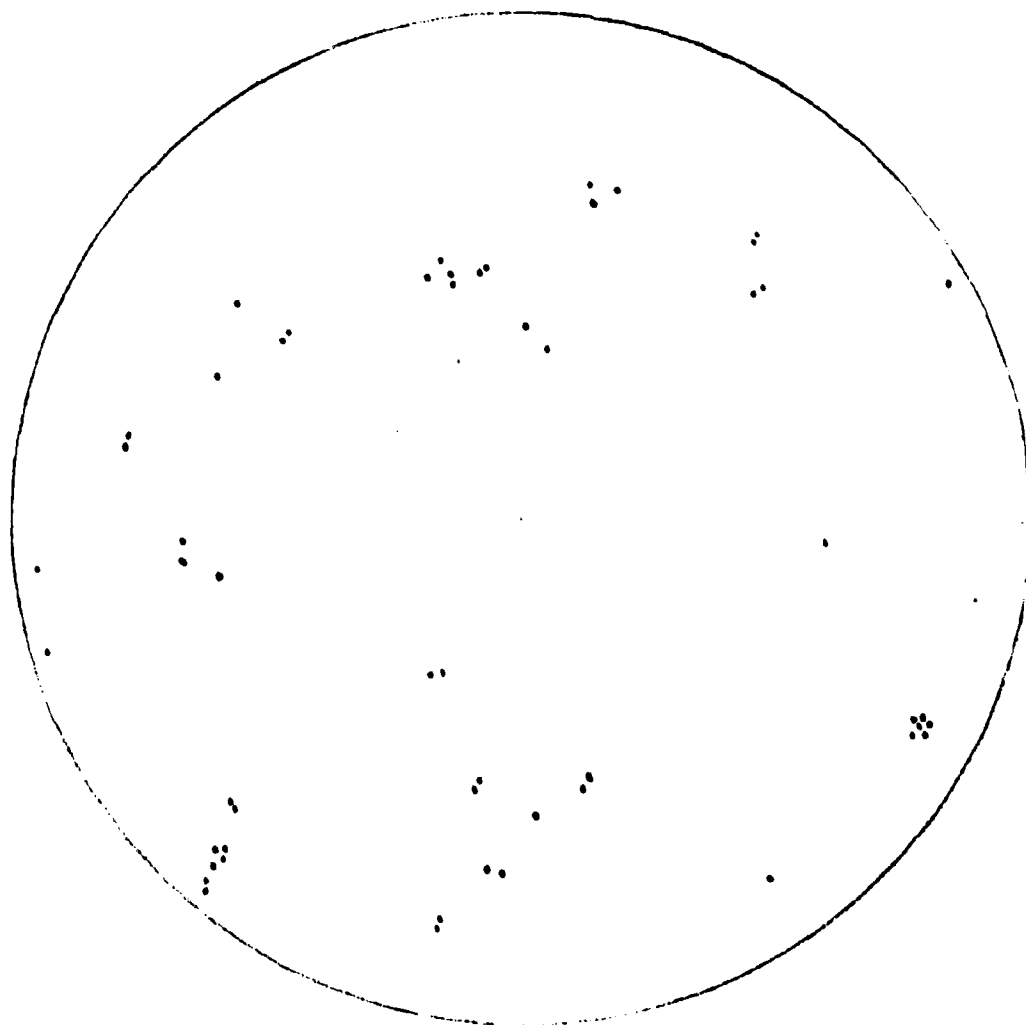


Figure 54. Sampling Variation of Randomness Ratio



Area = $225 \pi \text{ m}^2$

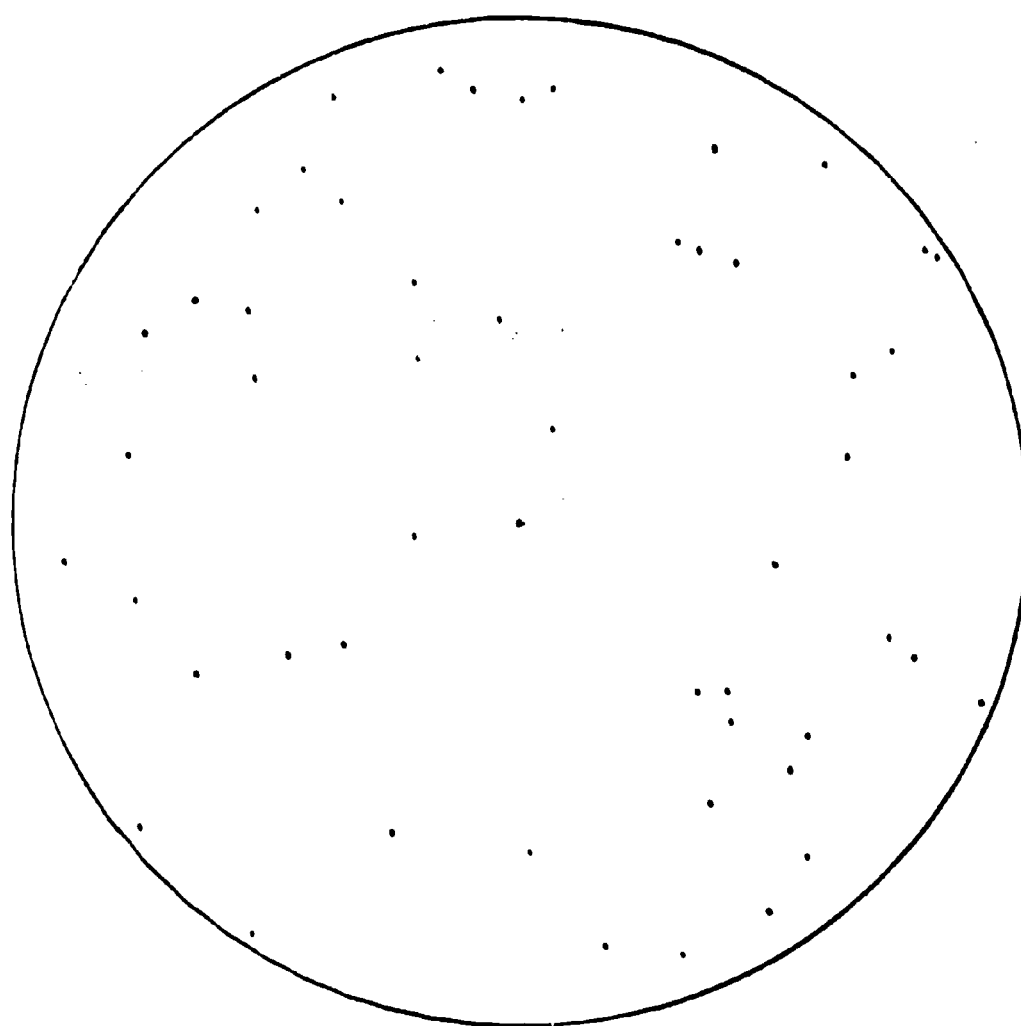
Site #20

Oak

Height Class 5

$R = 0.357$

Figure 55. A distribution of clustered points.



Area = $225 \pi \text{ m}^2$

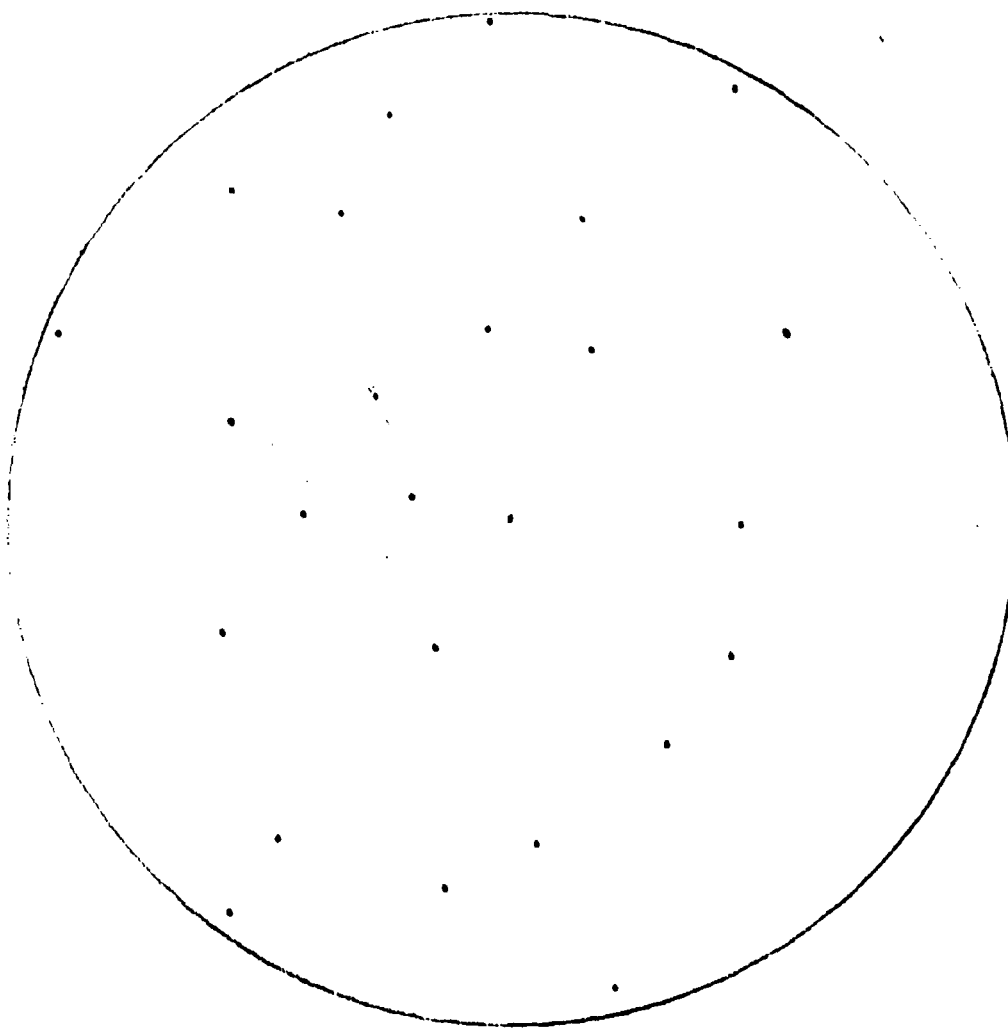
Site #68

Oak

Height Class 6

$R = 1.037$

Figure 56. A near random distribution of points.



$$\text{Area} = 225 \pi \text{ m}^2$$

Site #B-103

Loblolly Pine

Height Class 7

$$R = 1.310$$

Figure 57. A distribution of points which tend toward a uniform spacing.

include only a particular kind of tree at a particular height class. The population to be sampled could readily be either more inclusive or more exclusive. To illustrate one might be concerned only with the characteristics of clusters. In a population such as sampled in Figure 55 the clusters might be defined as consisting of n or more points each of which lie at no greater distance than r from its nearest neighbor within the cluster. Items of interest might be mean nearest neighbor distances within clusters or among clusters, or amount of cover within clusters. The above definition would, of course, exclude points which lie outside the clusters. Another population might be defined, however, which includes all or part of that group of points lying outside the clusters. Already referred to above is the probability distribution of a population of nearest neighbor distances. From Figure 52 it can be seen that as the mean of the nearest neighbor distances becomes relatively large, the distribution tends to become normal. The "shift" to the right can be noted in Figures 58 and 59. These graphs are based upon field observations in the Eglin and Benning areas. (Attention is called to the fact that the number of mean nearest neighbor distances varies from graph to graph and the reader should not be unwittingly misled by the height of the bars as presented.)

Variation in spacing of determinant structural elements within and among different communities of vegetation is summarized in Table V.

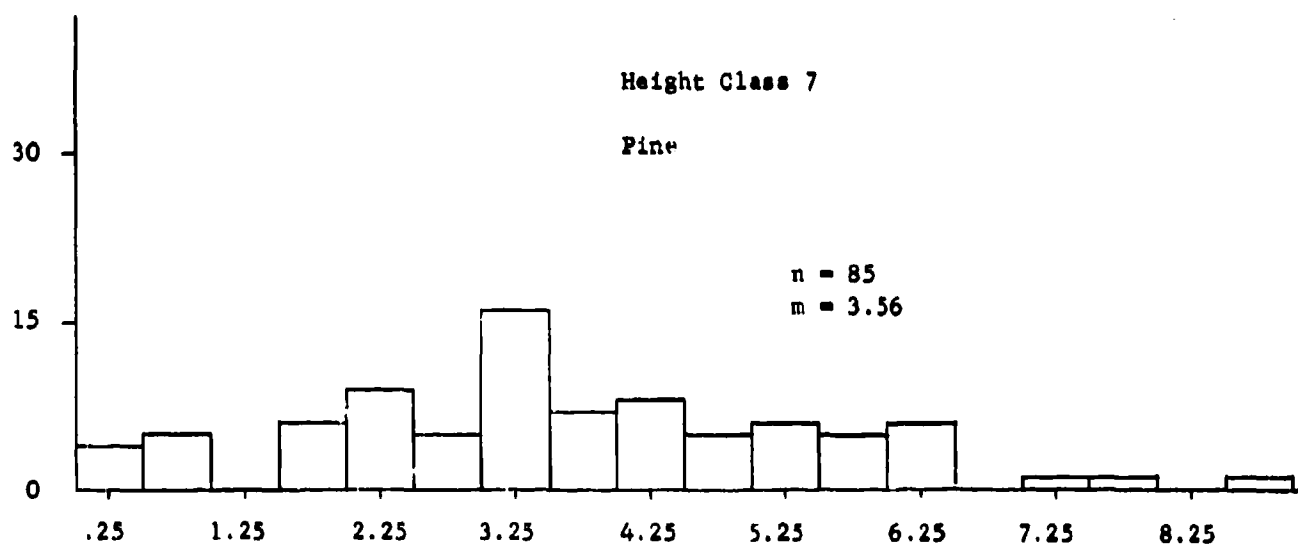
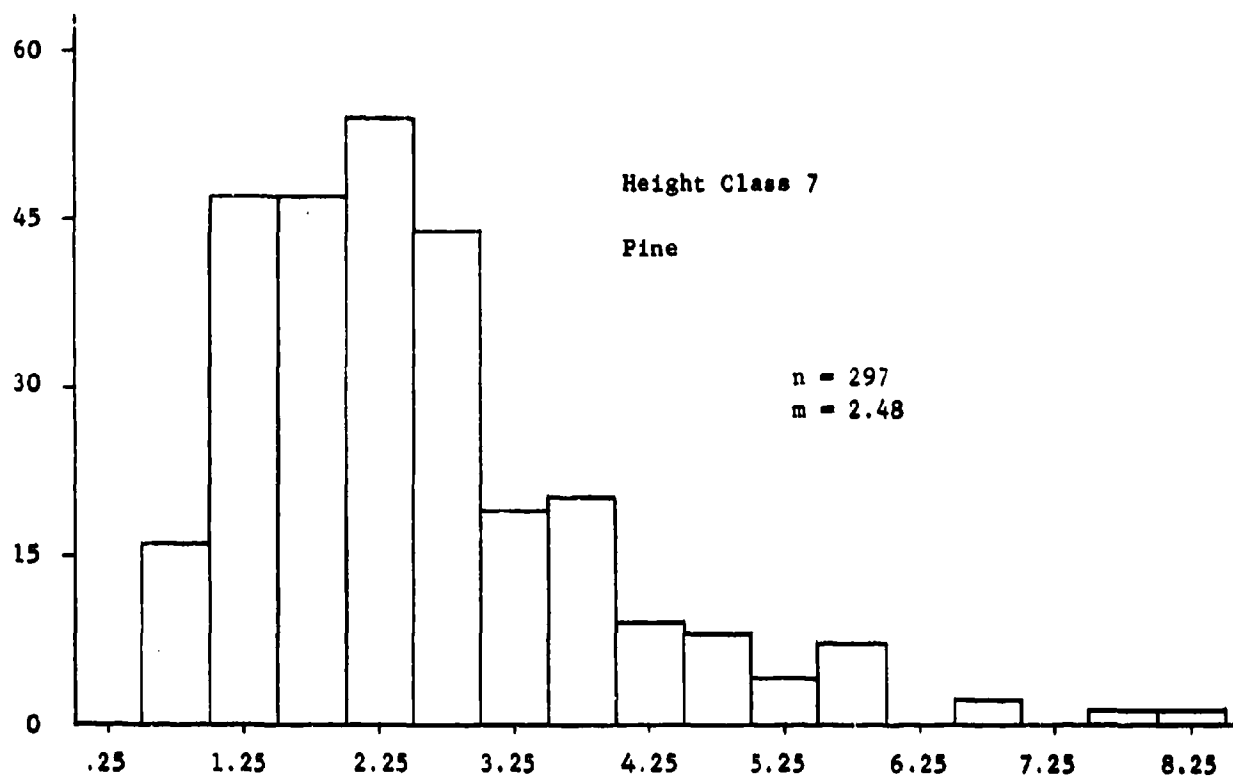


Figure 58. Distributions of nearest neighbor distances.

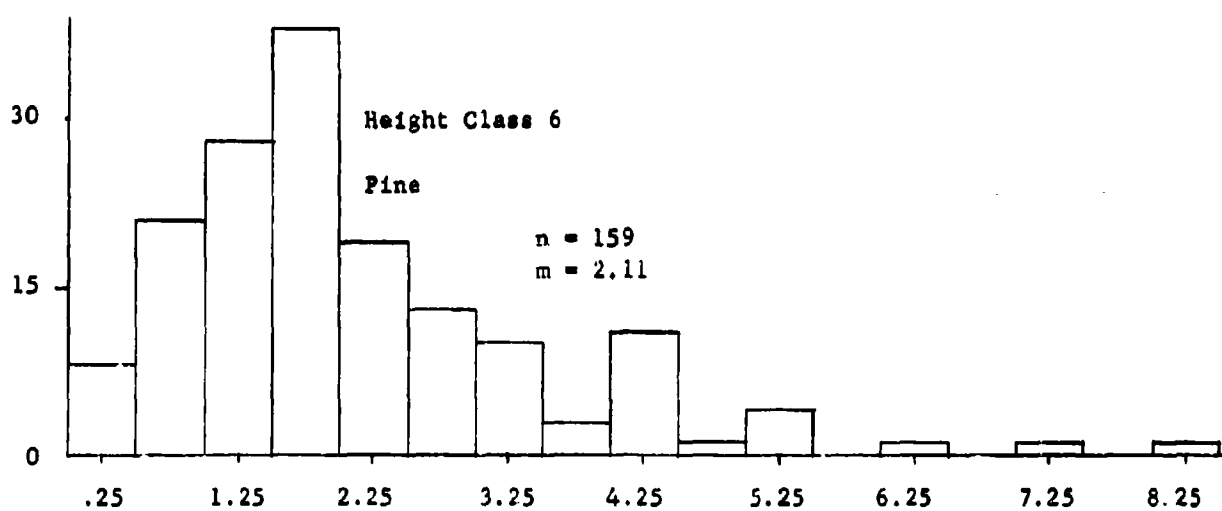
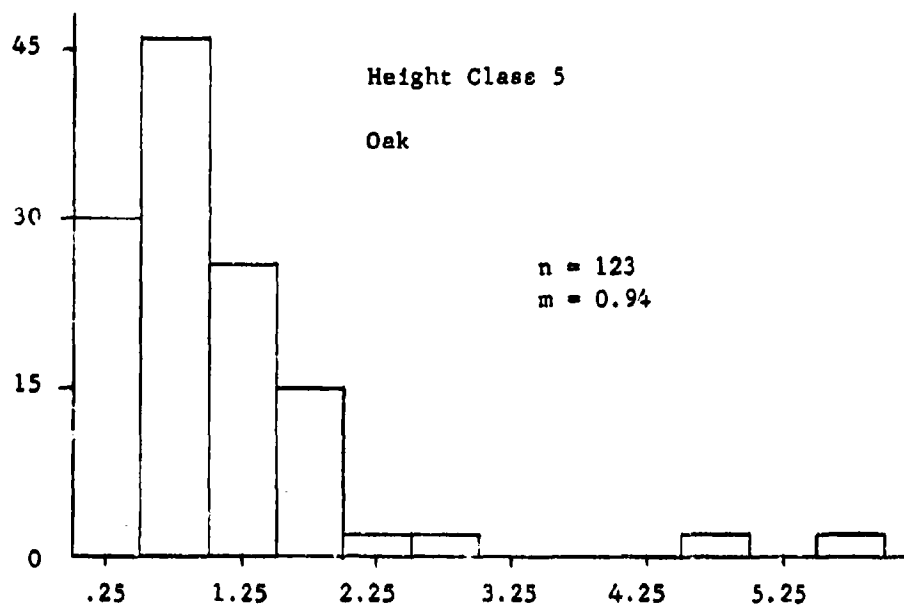


Figure 59. Distributions of nearest neighbor distances.

It is at once obvious that the groupings include limited numbers of samples and that ranges in variation are enormous. It is believed, however, that there are some trends.

Forests composed of pine have greater stem density in the Eglin area, but the trees are almost randomly distributed in both. The broad-leaved scrub oaks which are associated with the pines of the upland Eglin area in what appears visually to be a rather irregular pattern do have very wide ranges in their nearest neighbor distances and in their randomness ratios, but the mean of this group indicates randomness. Broad-leaved trees of the Benning area have relatively small mean nearest neighbor distances and tend strongly toward aggregation in their randomness ratios. Actually they fall well within the "clustering range" as defined by Mills (1964) in the Marshall University report. The Eglin area hammock trees have large and relatively regular spacing between them - as one would estimate from casual field observation.

Except for the Eglin scrub oaks, trees of the savanna-woodland type are generally widely spaced and strongly aggregated. The spacing is very wide at Benning, where military activities in the Glen Alta area have been especially prevalent.

In forests with thickets, the taller pines at Eglin are sparsely distributed and, if anything, trend toward regularity. By contrast,

TABLE V

Variation and Ranges in Stem Spacing

Variation and Ranges in Stem Spacing							
Elements and Communities	Number of Samples	Mean area per individual (square meters)		Mean nearest neighbor distance (meters)		Randomness ratio	
		Range	Mean	Range	Mean	Range	Mean
<u>Forest:</u>							
Height class 7, pine Benning	5	28.2-96.7	56.58	3.09-4.37	3.62	0.870-1.310	1.008
Height class 7, pine Eglin	10	10.4-137.0	31.69	1.58-3.44	2.41	0.412-1.260	1.017
Height classes 5, 6, broadleaf (scrub oaks) Eglin	9	3.54-93.5	23.38	0.56-6.29	2.33	0.596-1.298	0.993
Height classes 5, 6, 7, broadleaf (mixed hardwoods) Benning	6	8.03-44.8	29.15	0.88-3.09	1.74	0.510-1.003	0.729
Height classes 6, 7, broadleaf (hammock type) Eglin	5	10.40-93.5	38.10	1.59-6.29	3.39	0.986-1.298	1.141
All forests - Eglin	25	3.54-137.0	29.23	0.56-6.29	2.43	0.412-1.540	1.032
All forests - Benning	11	8.03-96.7	41.62	0.88-4.37	2.59	0.510-1.310	0.856
<u>Savanna-Woodland:</u>							
Height class 7, pine, Eglin	5	21.7-74.0	52.7	1.98-3.50	3.09	0.641-1.138	0.857
Height classes 5, 6, pine, Eglin	10	29.5-44.8	36.34	1.01-4.06	2.59	0.343-1.140	0.853
Height classes 5, 6, broadleaf (scrub oaks) Eglin	5	5.60-19.6	11.09	1.10-3.20	1.86	0.737-1.718	1.168
All savanna-woodland, Eglin	20	5.60-74.0	34.07	1.01-4.89	2.53	0.343-1.718	0.932
All savanna-woodland, Benning	4	16.0-113.2	64.30	1.74-3.74	2.65	0.602-0.870	0.714

TABLE V (Continued)

Variation and Ranges in Stem Spacing						
Elements and Communities	Number of Samples	Mean area per individual (square meters)		Mean nearest neighbor distance (meters)		Randomness ratio
		Range	Mean	Range	Mean	
<u>Forest with Thicket:</u>						
Height class 7, pine, Eglin	4	30.7-60.1	40.02	2.92-4.87	3.44	0.916-1.256 1.063
Height class 5, 6, pine, Eglin	1	-	8.1	-	1.50	- 1.057
<u>Old Field:</u>						
Mixture - one sample at Eglin, three samples at Benning	4	7.4-235.0	68.46	0.65-8.50	2.88	0.357-1.108 0.700
<u>Thicket:</u>						
Mixture - one sample each area	2	1.44-2.40	1.92	0.70-0.73	0.71	0.899-1.208 1.053

elements of old field vegetation, represented here by only four samples, trend strongly away from regularity and toward the patchiness typical of "weeds."

A method for rapidly and precisely determining minimal cell boundaries under diverse field conditions is still somewhat elusive.

By means of plastic overlays marked off into concentric equal area increments it has been possible to study the sample maps at some length. Twenty-five, ten, and five π series have been variously used, and it is quite possible to detect very small changes in mean area per individual from one subsample to the next. In a large majority of the maps examined to date, curves drawn to show the relation between numbers of individuals and mean area per individual achieve strong flexure about the time twenty individuals are involved. In other maps, pronounced leveling occasionally has been observed as low as at ten individuals and as high as with 30. Excepting extreme variation no explanation seems immediately available - in these latter cases departure from randomness may be toward or away from aggregation or nonexistent as indicated by randomness ratio. In general it does appear that leveling out occurs soonest in the stands having higher density. Stands with high mean areas per individual can and frequently do include a very large magnitude of variation. Also, cells contiguously spaced in what may visually pass as "same kind of vegetation" can have differing

diameters, mean nearest neighbor distances and randomness ratios.

Attempts to apply ordinary statistical procedures to a series of subsamples have been generally disappointing. For example, using 25 π increments, a 35-meter diameter sample can be viewed as consisting of a dozen subsamples of 78.5 square meter area. In stands of moderate density, the range of individuals per increment is often of the order of 0-5, and the variance becomes as large or larger than the mean. In a typical case the predicted number of similar subsamples necessary to obtain a standard deviation equal to ten percent of the mean was 44.

It would appear that direct measurement of nearest neighbor distances in the field accompanied by computation relative to the variation locally exhibited is most apt to yield "single samples" of highest value.

F. Problems and Recommendations

An adequate ratio of stems to crowns in the construction of the diagrams has not yet been achieved. Figure 60 presents the relation existing between number of stems present in the field and number of stems eventually depicted in the diagrams for 127 instances from 18 field samples. Some codified system such as developed by Mills (1964) would be helpful.

Studies of the relation between sampling by the "structural-

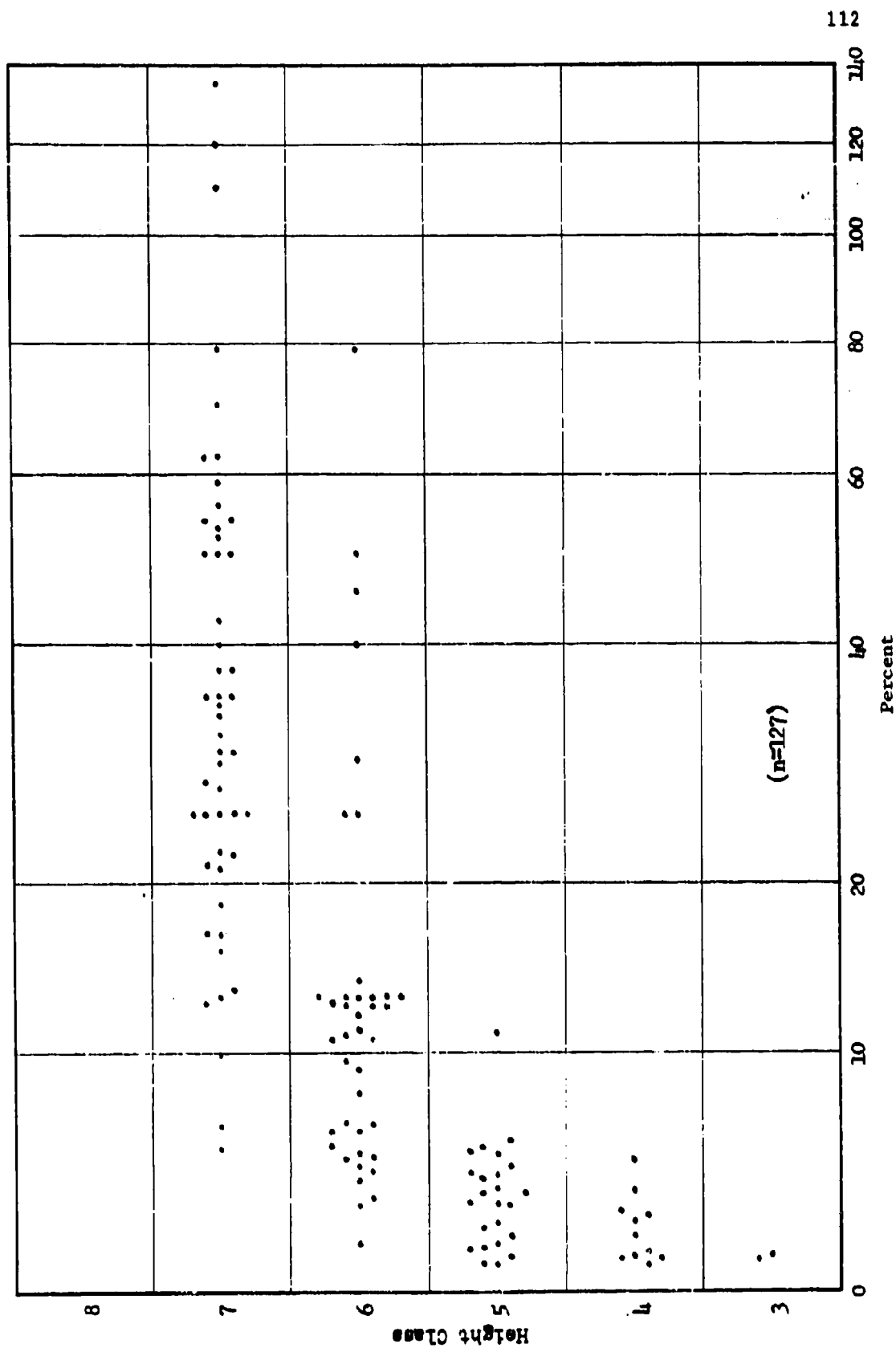


Figure 60. Percent of stems in field samples shown on vegetation diagrams.

element-area curve" and the "species-area-curve" should certainly be made. The flora of any area is already known to some degree, locally by common name or otherwise, and is apt to become even better reported in time to come. Species lists in supplement to structural or "physiognomic" aspects would more completely report the unique toxic, allergenic, and food-yielding qualities of the vegetation of an area.

Only a start has been made on the problem of vegetation map construction from large-scale aerial photos. It is believed that crown studies by trained observers may lead to at least simple distinctions regarding crown cover and also perhaps stem density. A next step might consist of intensive sampling on the structural cell basis in an area already well known and photographed especially with different films at a series of scales. There ought to be a way of detecting something as large as a tree trunk viewed end-on from above.

V. RETROSPECTIVE ADDENDA TO THE RANGER STUDY

A. Macrogeometry

Macrogeometric analysis is an attempt to classify terrain in a simple and unambiguous manner, which at the same time will provide enough differentiation among varying expressions of topography to be useful to those requiring the information. Classification of any kind involving some systematic arrangement of symbols to represent an actual condition that exists is a form of model building. Obviously, depending on need, models range from simple to complex.

The seven parameters used in macrogeometric classification (elongation, relief, dissection, profile area, slope, peakedness, and parallelism) (Vanderbilt University, 1962, 1963; and elsewhere in these reports) were designed to describe uniquely in profile and plan view, and by orientation, any given terrain unit or group of terrain units through statistical analysis. With the exception of slope*, which depends upon the ratio of relief to dissection, these parameters are independent of each other over wide enough ranges to provide a considerable amount of descriptive variation from area to area. Likewise, this independence allows for one or more parameters to remain fairly constant over several

* A slope value becomes relatively large as the relief becomes relatively large; it becomes relatively small as the dissection becomes relatively large. Slope remains constant over a proportional change in relief and dissection.

terrain areas of interest while other parameters vary widely from area to area.

The several terrain unit parameters provide a generalized picture, a characteristic of all models. This in itself is no criticism of the resulting model. More or fewer parameters may provide more or less generalization, respectively. Likewise, a different set of parameters may and likely would provide different information. A particular statistical model is usually designed to obtain a particular kind of information, often with some given amount of detail and level of validity and reliability.

With regard to statistical analysis and model building, certain points, perhaps elemental to some, should be stressed:

- (1) The assumptions and generalizations inherent in statistical analysis may be overlooked in building a model by this means. A weak and unreal model may result. Furthermore, such analysis may be as yet unusable or too costly.
- (2) Statistical analysis must evolve in logical order from experimental design to the kinds of data required and the methods of collection. The latter must be rigorously followed if the planned use of the data is to have value.
- (3) Data collected for one previously designed purpose very likely cannot be used for another without leading to the

same questionable results derived from no a priori planning at all (Deming, 1950, pp. 1-52; Kurnow, 1959, pp. 1-49).

If either of these procedures is followed, limitations upon the use of the results should be made known in presenting them.

- (4) Experimental design involving statistical analysis requires a close working relationship between the mathematical designer and those in the field of application, each recognizing the objectives and the problems of the other.

High priority in the matter of interdisciplinary cooperation implied in the last point listed above must be given to the mutual understanding of definitions. The meaning of the sample is a case in point. Too often the sample is regarded by the non-statistician as a miniature replica of the whole, or population, from which it was taken. Actually, one can only infer certain characteristics of a well defined population from a well defined sample. Such inferences always carry an element of doubt, but it is the ability of statistical analysis to quantify this doubt.

A population is made up of an aggregate of individual elements but it is an entity in its own right. Except in instances where the variation from element to element is essentially zero, a sample consisting of only one element is a poor representation of the entire population.

Population characteristics, or parameters, are equally poor representatives of individual elements. Statistical treatment of a group of individuals dissolves their individuality and merges them into a new and single entity. The statistician is usually interested in only a few characteristics of an element, perhaps only one, per population, and even these are often grouped into classes thereby effectively destroying individuality.

An element does not necessarily belong uniquely to one population. An apple, for example, can belong to a population of delicious apples, pome fruits, fruit, food, etc. Such combinations can be shown effectively through the use of a Venn diagram (Figure 61) or similar commonly used device.

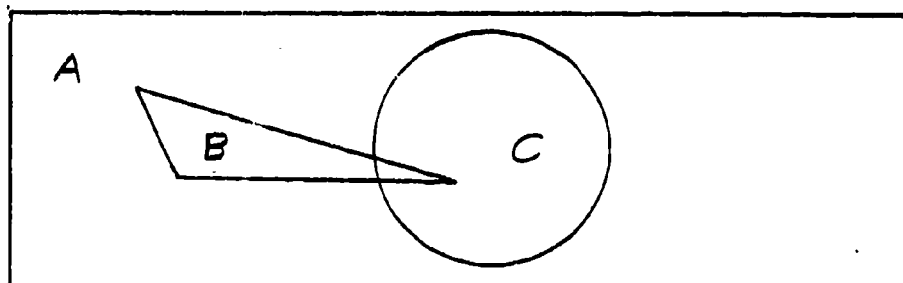


Figure 61. Venn Diagram

An investigator may be interested in some characteristic common to all elements of Set A in the diagram. On the other hand, he may be concerned with all of Set A excepting Set C. Other possible combinations would include Sets B, B not C, BC, and B and C. Samples of a set of characteristics are themselves unique sets from which inferences may be drawn concerning the parent set, or in statistical parlance, the population.

When a sample is to be drawn from some defined population for the purpose of estimating certain characteristics of that population one should determine in advance, among other things, a sample size. For the most part the sample size is dependent upon the variability of the data being sampled; i.e., the greater the variability, the larger the sample size needed for some given confidence interval, sometimes called prediction interval. A priori planning is essential unless one is willing to be content with estimates which are bounded by excessively wide limits due to under sampling or be willing to bear the expense of over sampling in the hope of obtaining estimates which are narrowly enough bounded to be useful.

A most common method* of determining the number of random observations needed utilizes the relationship $\sqrt{n} = ts/d$ where n is the sample size needed after the half-length of the desired confidence interval, d , has been decided upon. The estimated standard deviation, s , usually must be estimated from a preliminary sample, and t is a tabled value which depends upon the desired level of confidence and one less than the number of observations in the preliminary sample. Certainly the investigator has no control over the variance, s^2 , in a defined population. With this in mind it is obvious that where s is large in the above equation the (half-length) confidence interval, d , also must be large if there is no compensating increase in the size of n . (Steel, 1960,

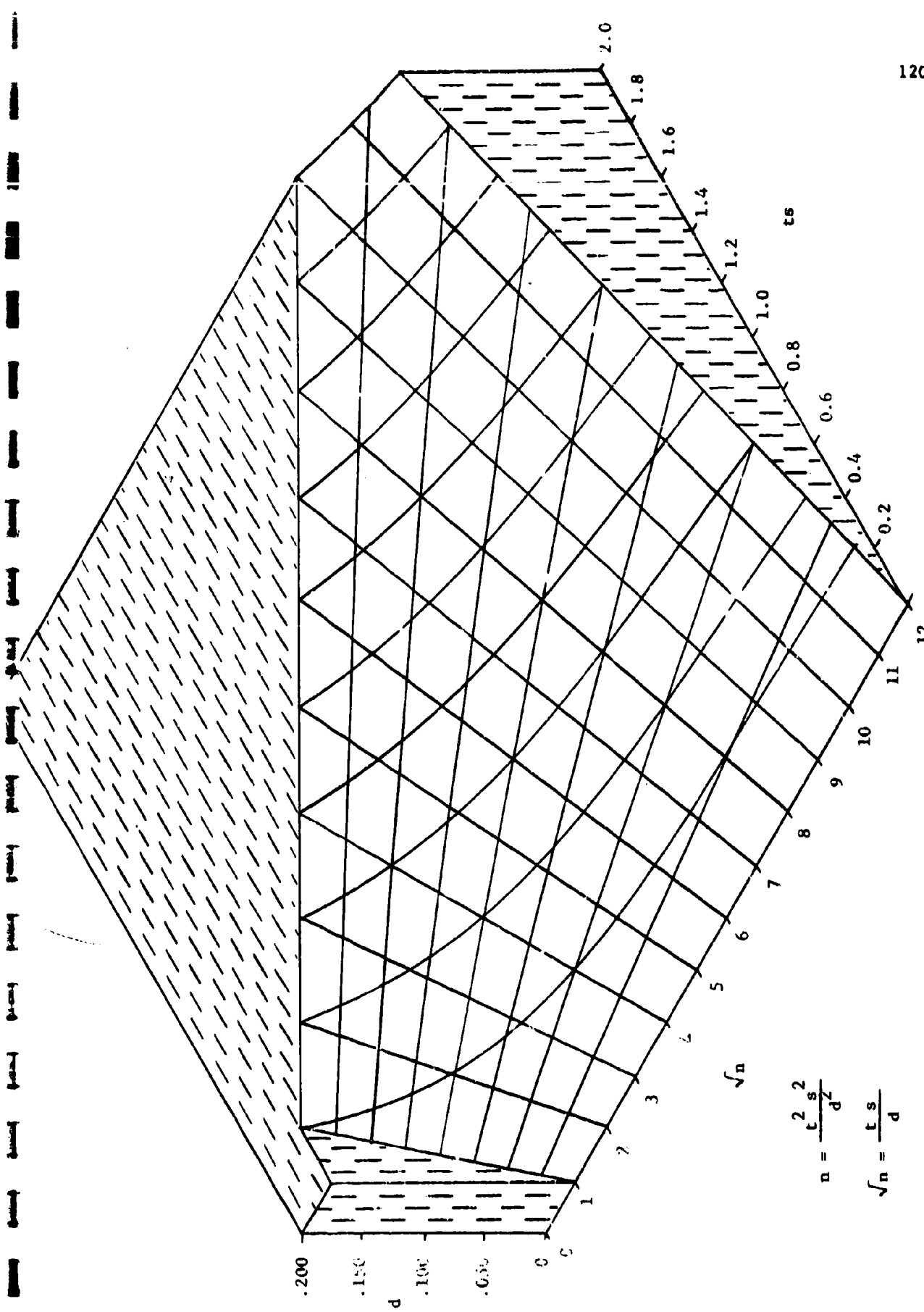
* Repeated from Part 1 (1963 for emphasis.

pp. 86-87; Deming, 1950, pp. 53/-5/1). This relationship is shown graphically in Figure 62.

In instances where the population variance is already known with a reasonable degree of certainty there is no need to estimate it from a preliminary sample. The sample size is then determined from the equation, $\sqrt{n} = z\sigma/d$, where z is a tabled value that depends only upon the desired level of confidence, and σ is the population standard deviation; σ^2 is the population variance. Figure 32 on page 84 of the Dahlonga report shows the relationship between the confidence interval and the sample size where the standard deviation is held constant.

From the above discussion it follows that one cannot speak of any given sample size as being adequate until (1) the population variance is known, and (2) the level of precision, i.e., the confidence interval, is determined. The level of precision needed may vary from researcher to researcher to practitioner depending upon the uses to be made of the findings.

Once the preliminary decisions are made and the samples have been obtained it may be desired to utilize the data for purposes other than description. To illustrate, the variances and means of the elongation numbers for the Dahlonga, Benning, and Eglin areas respectively will be compared in order to determine whether or not they could have come from the same population. The level of significance used is 5%.



$$n = \frac{t^2 s^2}{d^2}$$

$$\sqrt{n} = \frac{t s}{d}$$

Figure 62. The sample size n , varies directly as the variance, s^2 , and inversely as the confidence interval, $2d$, desired. (d is the half-length confidence interval.)

The problem is to determine whether differences between the values tested are so great that such differences could occur in no more than 5% of all possible samples if the population values (parameters) are indeed equal and the differences are occurring by chance alone. Figure 63 shows graphically the three sample distributions of elongation numbers with normal curves based upon the respective sample means and variances obtained. (Each of these curves is only one of many, for the respective means and variances themselves fall within confidence intervals over which one can be certain only to some degree, say 95%, that the population curves actually lie within those limits.)

The test may be developed as follows: (Li, 1961, pp. 105-118; Steel, 1960, pp. 82-86)

(1) Hypothesis: $\sigma_1^2 = \sigma_2^2 = \sigma_3^2$

(The hypothesis states that there is no difference in variation of elongation of terrain units between the Dahlonga, Benning, and Eglin areas at a given significance level.)

(2) Alternative hypothesis: $\sigma_1^2 \neq \sigma_2^2; \sigma_1^2 \neq \sigma_3^2; \sigma_2^2 \neq \sigma_3^2$

(3) Assumptions: The given samples are random samples drawn from a normal population. (Rigor is lost as the method for drawing the samples deviate from randomness, except in the special cases, and as the population deviates from normal.)

(4) Level of significance: 5%

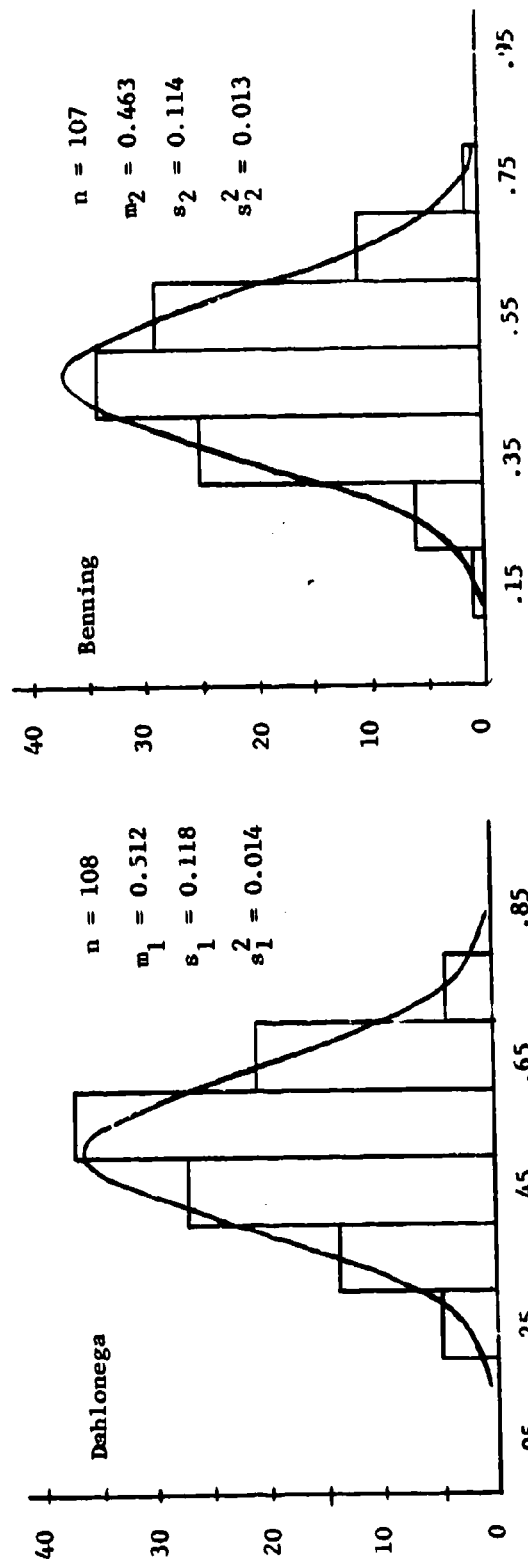
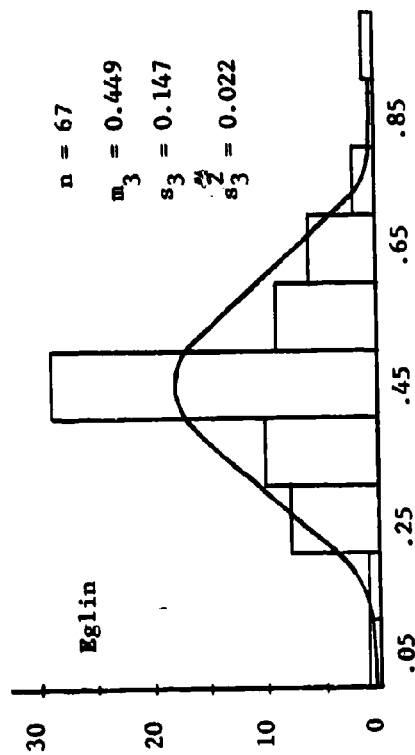


Figure 63. Frequency distributions of sample terrain unit elongation numbers superimposed on a normal curve of same number (n), mean (m), and standard deviation (s) for each distribution.

$$\begin{aligned}
 (5) \text{ Critical regions: } F(0.025; 120, 120) &= \frac{1}{1.4327} \text{ and } 1.4327 \\
 &= 0.6980 \text{ and } 1.4327 \\
 F(0.025; 60, 120) &= \frac{1}{1.5810} \text{ and } 1.5299 \\
 &= 0.6325 \text{ and } 1.5299
 \end{aligned}$$

(The F-test, s_1^2/s_2^2 , is called the variance ratio. The ratio is equal to one if the variances are equal; however, sampling variation will likely yield variance estimates which are greater or less than the true variance. The critical regions are those regions outside of which the ratio, s_1^2/s_2^2 , of all possible tests resulting from comparing a large number of sample variances, taken from the populations with $\sigma_1^2 = \sigma_2^2$, will fall over some given portion, say 95%, of the number of times tested. Relatively large sample sizes permit relatively short test intervals. In these instances, $0.6980 > \text{critical region} > 1.4327$ for 120 degrees of freedom in the numerator and 120 degrees of freedom in the denominator and $0.6325 > \text{critical region} > 1.5299$ for 60 and 120 degrees of freedom. The "degrees of freedom" is equal to one less than the number of observations in the sample; however, one must read to the nearest value in the tables available.)

(6) Determination of F:

$$\text{Dahlonge } s_1^2 = 0.014 \text{ with } 107 \text{ d.f.}$$

$$\text{Benning } s_2^2 = 0.013 \text{ with } 106 \text{ d.f.}$$

$$\text{Eglin } s_3^2 = 0.022 \text{ with } 66 \text{ d.f.}$$

$$F = \frac{s_1^2}{s_2^2} = \frac{0.014}{0.013} = 1.08 \text{ (not in C.R.)}$$

$$F = \frac{s_1^2}{s_3^2} = \frac{0.014}{0.022} = 0.64 \text{ (not in C.R.)}$$

$$F = \frac{s_2^2}{s_3^2} = \frac{0.013}{0.022} = 0.59 \text{ (in the C.R.)}$$

(7) Evaluation of test:

- (A) It is quite possible that elongation is the same for the Dahlongega and Benning areas based upon the F-test at the 5% level of significance.
- (B) Elongation variation may be the same for the Dahlongega and Eglin areas, but there is cause for doubt at the 5% level of significance.
- (C) Elongation variation in the Dahlongega area probably is not the same as elongation variation in the Eglin areas at the 5% level of significance.

It should be pointed out that statistical manipulation does not relieve the researcher of the responsibility of making subjective decisions based upon his own knowledge and ability to reason. The results of the above F-test are meaningless to the person not reasonably well acquainted with elongation as it is related to the macro-geometry of this report. The same results may well have different meanings to two or more different applications of the model.

Another test commonly used is one to determine the probability of two sample means having come from the same population. It is illustrated by setting up the procedure without detailed calculations.

- (1) Hypothesis: $\mu_1 = \mu_2$.
(The two means being tested here are elongation means from Dahlongega and Benning samples respectively.)
- (2) Alternative hypothesis: $\mu_1 \neq \mu_2$.
- (3) Assumptions: Random samples have been drawn from normal populations and the populations have the

same variances; i.e., they are outside the critical regions of the F-distribution at the 1% level.)

(4) Level of significance: 5%

(5) Critical regions for \underline{t} with $n_1 + n_2 - 2$ degrees of freedom:

$$t_{.025,120} < 1.980 \text{ and } t_{.025,120} > + 1.980$$

(The distribution of sample means follows the \underline{t} distribution which is extensively tabled. If the calculated \underline{t} of (6) below is less or greater than -1.980 and + 1.980 respectively it will be concluded that the population means are different, for such a calculated value could occur only five times out of a hundred if caused by chance alone.)

(6) The detailed procedure for this calculation are available in almost any statistics text. In this instance,

$$t = 0.253$$

This is well outside the critical regions; thus, the hypothesis is accepted without a great deal of suspicion. It should be noted, however, that there is always some small chance that populations of different mean values will give sample means which are similar in magnitude.

Each of the above tests required certain assumptions including the assumption of normality. This assumption is most important, for a major part of statistical analysis is built upon normal distributions. Logarithmic transformations were used elsewhere in this report (pages 56-58 along with a note of caution (Gumbel, 1958, p. 345), in an attempt to obtain normal distributions in the case of dissection and relief values. Theoretically it is possible to transform any population into a normal one providing the population distribution is known.

This latter bit of knowledge, however, is often most difficult to obtain (Li, 1961, pp. 447-484). While one may find a hint in empirical data, very little dependence can be placed in a single sample distribution being a "true" representative of the population. This would be equivalent to estimating the relief of an area from a single observation. Inasmuch as the population distributions for the several macrogeometry parameters are unknown, application of the logarithmic transformation was a "shot in the dark."

One possible solution to the dilemma of unknown and difficult population distributions may lie in the development of non-parametric or distribution-free methods of analysis. Whatever the solution, however, it is recommended that it be found in order that future investigations yield sample estimates of the (population) parameters which are valid and reliable, and which lie within short enough intervals of confidence to be useful. This in itself would seem to be a worthwhile project.

Any project to determine the population distributions of the several macrogeometry parameters discussed elsewhere in this report should include a preliminary investigation based upon some working hypothesis utilizing available data, both theoretical and empirical, in order that reasonable assumptions can be made with regard to the desirability of retaining all or part of this particular set of param-

eters for describing terrain macrogeometry. It may be that some or all of these distributions can be determined mathematically. An example of this can be found in this report on page 95 where the distribution of interest is that of nearest neighbor distances within a random distribution of points over a plane.

It was stated above that "one cannot speak of any given sample size as being adequate until (1) the population variance is known, and (2) the level of precision, i.e., the confidence interval, is decided." A terrain unit that is a conic section with circular base is without variation within such measurements as relief, dissection, and slope. As the unit becomes more and more irregular, however, the variation within a particular set of measurements becomes greater and greater. If a random sample size is allowed to emerge when the per cent difference between the means of n_1 and $n_1 + a_1$ (n_1 and a_1 are independent and $i = 1, 2, \dots, k$) observations differ by some amount, say 5%, it appears that an undue amount of chance variation is permitted. The per cent difference is quickly and easily determinable, but it increases the amount of work by chance over sampling on the one hand and decreases the amount of precision by chance under sampling on the other hand. An alternative would be to calculate the sample variance as measurements are made. Ultimately some reliable "short-cut" method might be arrived at which is based upon increasing amounts of empirical data. On the

other hand some satisfactory non-parametric method may be found.

Some empirical evidence of the independent nature of the several terrain unit parameters, except as noted above (page 114) may be found by comparing those sample values which lie within the extremes of the range. Those "atypical" values for the Benning and Eglin areas are listed in Table VI.

For some given area-slope-characteristic range, one would expect large relief values to be accompanied by large dissection values. This can be noted among the values of Table VI. Likewise, as noted above (page 114) large slope values might be expected to be associated with relatively large relief values and relatively small dissection values. Unfortunately, the skewness of the distributions and the lack of a population transformation equation makes precise treatment of the data impossible. For a comprehensive treatment of extreme values see Gumbel, 1958.

B. Vegetation

A general summary of the three regions would indicate that although each is clothed principally by a forest, there are several other kinds of plant assemblages that are representative and that wide variance exists within and among all of them. As an example for internal comparison, average percent cover by height class is shown in five kinds

TABLE VI
ATYPICAL TERRAIN UNITS

S-Small

L-Large

(Eglin)							(Benning)						
Number	E	R	D	A	S	Θ	Number	E	R	D	A	S	Θ
22-80-1	S						78-18-3	L					
22-74-1	S						80-18-1	S	L	L			
17-74-1	L						80-18-2	S					
25-70-1	L						79-18-3	S				L	
24-76-1	L						76-06-2	L					
07-80-1		L				L	75-05-3	S					
13-78-1		L					79-17-4		L				
14-80-1		L				L	79-19-1		L				
16-77-1		L					81-17-1		S				
21-80-1		L	S			L	78-06-1		S	S			
22-78-1		L	L				77-18-1		L	L			
23-76-1		S	S				79-17-2		L	L			
23-77-1		S					79-17-3		S	S			
25-77-2		S					79-18-1		S	S			
11-80-1						L	79-20-1		S	S			
17-70-1						L	80-19-1		L	L			
21-88-1						L	78-17-1		S				
22-81-1						L	78-19-3		L		L		
26-77-1						L	80-20-2			S		L	
05-76-1			L				77-20-1				L		
11-78-1			L				78-19-1				L		
15-73-1			L				80-20-1				L		
24-71-1			S				76-05-3				S		
							76-07-1				L		
							78-03-2				S		
							79-04-2				S	L	
							75-05-4				L		
							73-05-2					L	
							76-05-2					L	
							76-06-2					L	
							79-05-2					L	
							77-06-1					L	L
							78-18-2						L
							79-19-2						L
							79-19-3						L
							80-16-2						L
							80-18-3						L
							78-04-3						S

of communities from the three regions in Figures 64-68. The areas selected include much of the variety of vegetation that exists in the southeastern United States and therefore provide a good testing basis.

The aspects of cover, stem density, and height as characteristics of primary significance in terms of military application have been studied in detail and used as a focal point for bringing together the detail of ground sample information with that obtained from interpretation... of aerial photographs or inherited from descriptive literature. The categories developed as mapping units are offered as suggestive rather than exhaustive entities, and it is hoped that their inherent naturalness and possible utility may be tested objectively at an early date. Assuming continuation of interest in any of them, it would be possible on the basis of the current pilot series to erect a planned sampling program which would yield much more definitive information about them.

C. Other Environmental Factors

In areas other than macrogeometry and vegetation, upon which major emphasis was placed in this study as required, a complete evaluation and summary of results could not be properly achieved within the time limitations imposed. Objectives in these areas were never clear-cut and collection of data followed no experimental design. Relegated to lower rank by matters of greater interest or priority, many of these environ-

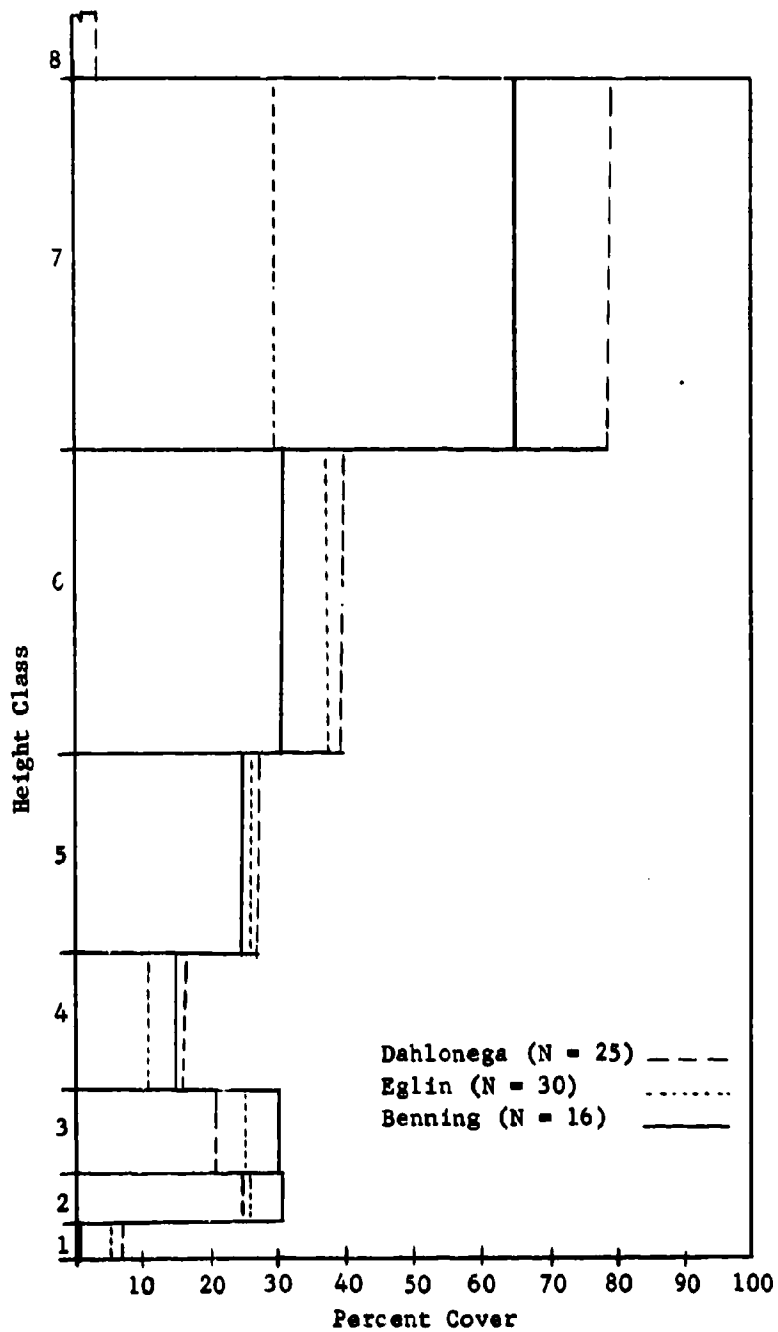


Figure 64. Comparison of average cover per height class in forests from different regions.

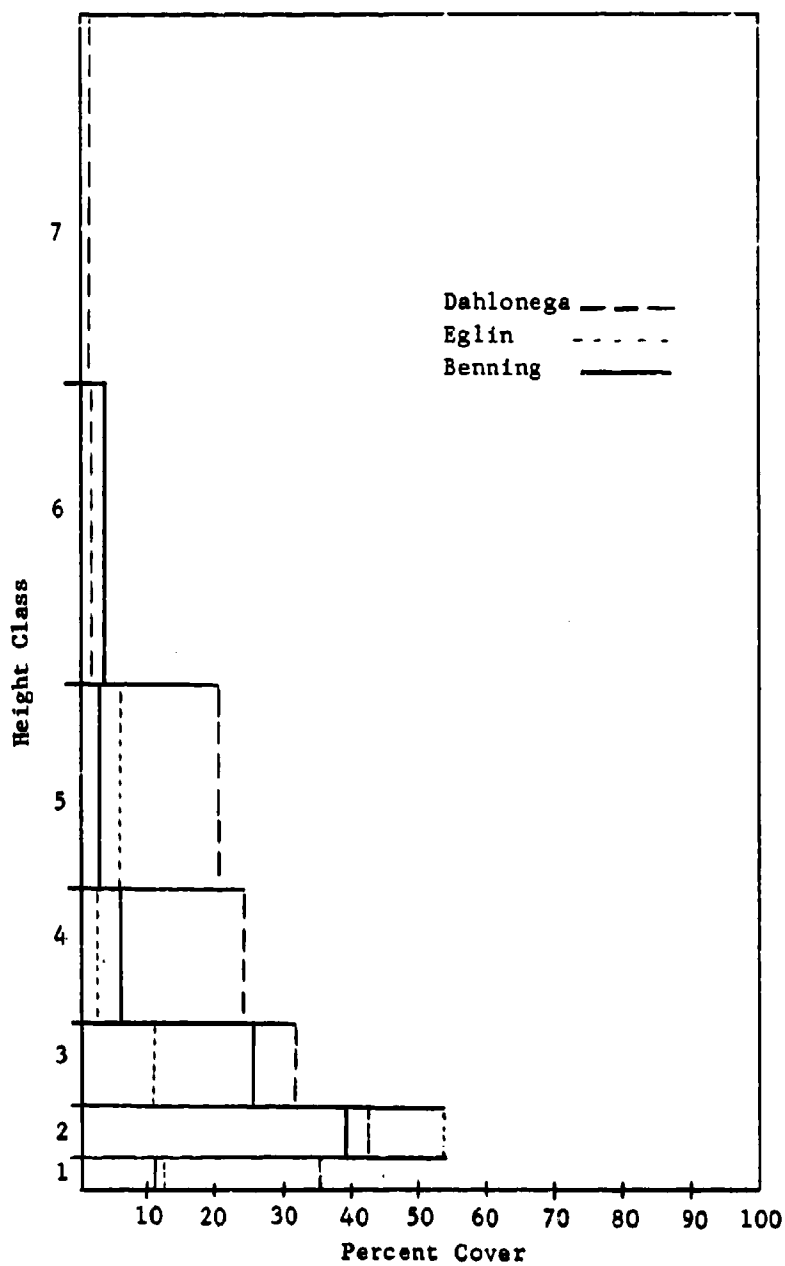


Figure 65. Old fields.

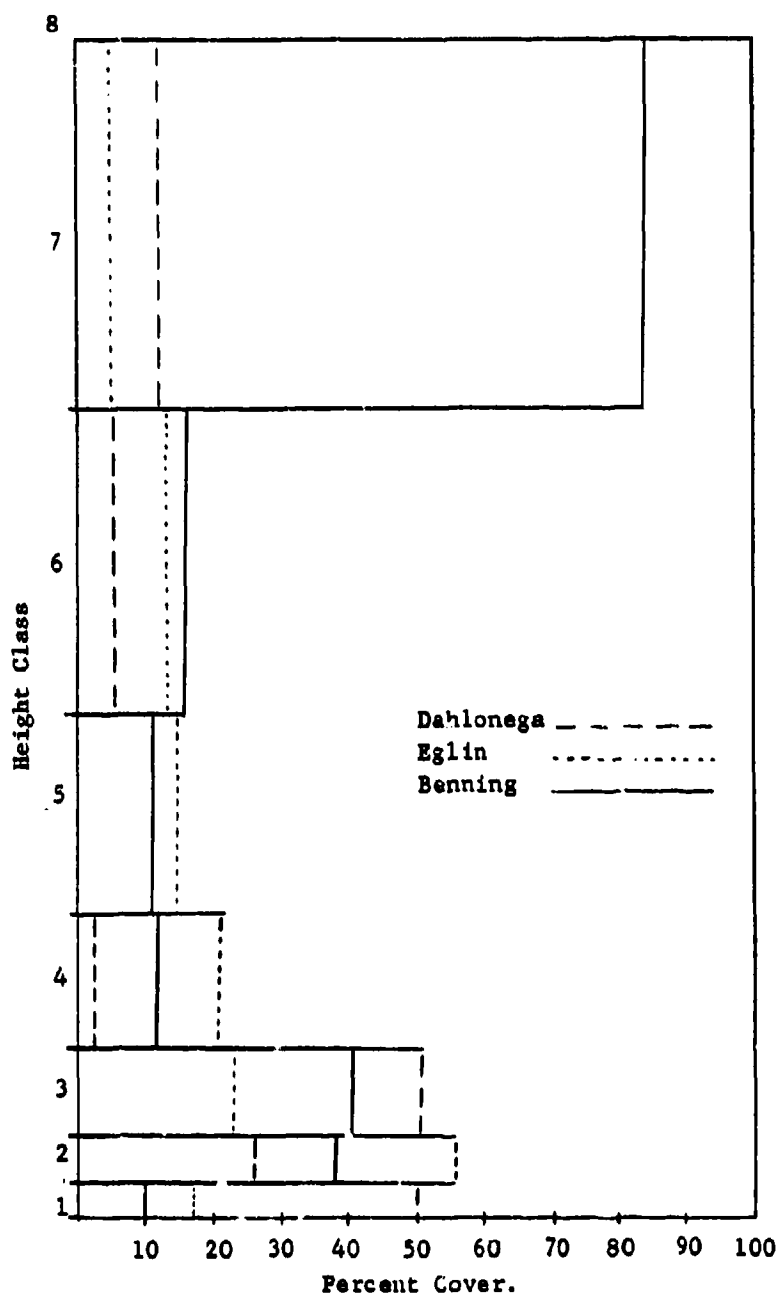


Figure 66. Comparison of average cover per height class in Savanna (park)-Woodlands from different regions.

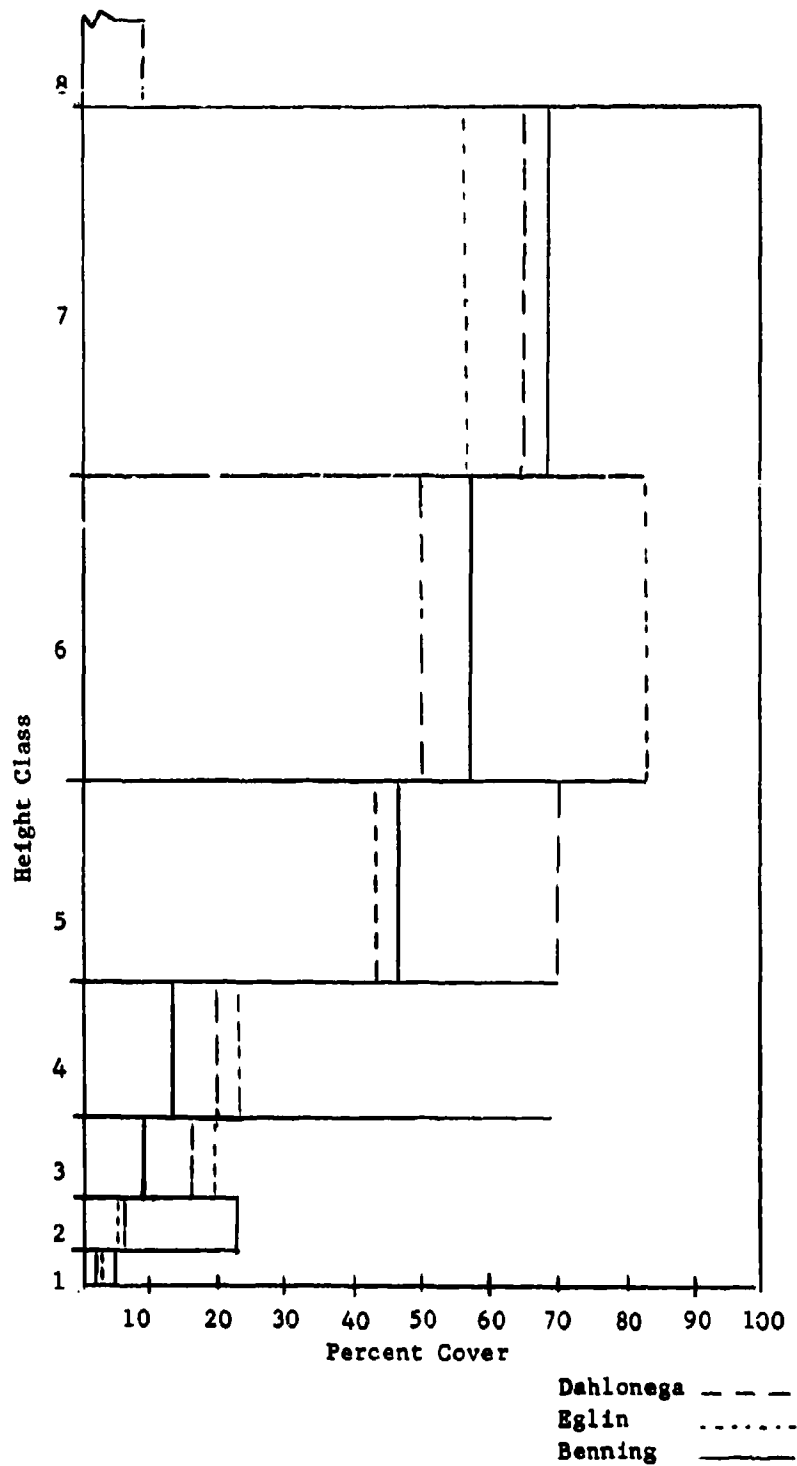


Figure 67. Forests with thickets.

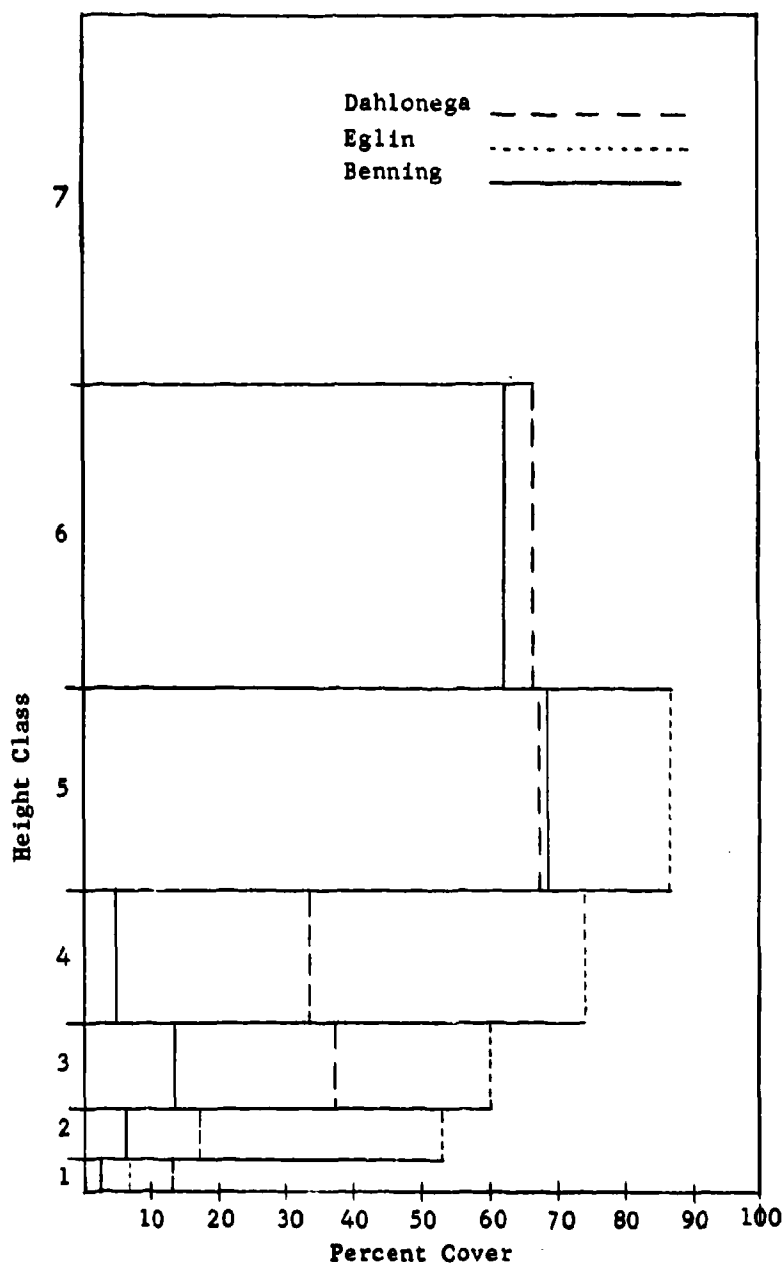


Figure 68. Comparison of cover by height classes in thickets.

mental factors have been only partially examined and none to the point of comprehensive quantification. On the other hand, it is believed that all of the features of the Ranger training areas appearing to have some bearing upon the central problem of military environment have been recorded, their relative influences evaluated, and, to some extent, measured. From this has emerged a number of possibilities for further examination and, in a few cases, experimental procedures along such lines have been carried out.

In view of the inadequacy and inconsistency with which individual environmental factors were examined among the three Ranger areas, it is not possible to compare areas in terms of every factor examined. However, the conclusion appears inescapable that each area is unique in that factors more important in one area have lesser influence elsewhere; consequently, it would be extremely difficult to fit each area to a common mold. Surface materials, for example, would appear to demand greater attention in the north Georgia area than in either of the other two areas. Hydrologic factors are of prime importance in the Eglin Field area, or perhaps more specifically, the land-water interface. At Eglin Field, it has been suggested that the generally recognized surficial boundary is less important than the vertical one. The intensity of a number of environmental influences at Fort Benning appears to be intermediate in character when contrasted with the other areas. At the same time, the degree of development of minor-scaled terrain features at Fort Benning is, while not unique perhaps, unusually high.

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